

Swyface PREPARED

Gas Atmospheres

every heat treatment of ferrous and non-ferrous metals

	* SIZES OF	METAL TO BE TREATED					
TYPE OF GAS	AVAILABLE UNITS	COPPER	LOW C. STEEL UP TO B JO C	MED C STEEL 0 20-0 60 C	HIGH C STEEL	SPECIAL STEELS	
DX GAS (LEAN) 40° F. DEW POINT	250 TO 35,000 CU. FT. PER HOUR	BEIGHT				_	
DX GAS (RICH) 40° F. DEW POINT	250 TO 35,000 CU. FT. PER HOUR		BRIGHT ANNEAL	UP TO 30 MIN. EXPOSURE BRIGHT ANNEAL AND CLEAN HARDEN			
MX GAS	1,000 TO 20,000 CU. FT. PER HOUR	BRIGHT ANNEAL	BRIGHT	BRIGHT ANNEAL CLEAN HARDEN	BRIGHT ANNEAL CLEAN HARDEN		
RX GAS	250 TO 3,500 CU. FT. PER HOUR	Oxygen, O ₂ , is the only one of the common gases	CARBURIZE DRY CYANIDING	CARBURIZE BRIGHT ANNEAL CLEAN HARDEN CARBON RESTORATION (SAIN BECOVER! DRY CYANIDING	BRIGHT ANNEAL CLEAN HARDEN		
CHAR-MO GAS	500 TO 1,000 CU. FT. PER HOUR	which reacts with copper. conse- quently, the atmos- phere generator may be dispensed with in the bright annealing of that metal it is only nec- essary to set the	CARBURIZE	CARBURIZE BRIGHT ANNEAL CLEAN HARDEN	BRIGHT ANNEAL CLEAN HARDEN	CLEAN HARDEN TUNGSTEN MOLYBDENUM STEEL	
AX GAS (DISSOCIATED AMMONIA)	S00 TO 4,000 CU. FT. PER HOUR	furnace burners slightly rich to pre- vent free axygen within the furnace				BRIGHT AMNEAL STAINLESS STEEL	

*Where larger capacities are required multiple units can be supplied.

• Surface Combustion research in the development and use of specially prepared gas atmospheres for all heat treatments of ferrous and non-ferrous metals has made possible metallurgical results of such significance that it goes beyond the mechanical details of furnace construction. Today, with the use of 'Surface' indirectly heated furnaces—radiant tube heating elements and muffle type units and Surface' Prepared Gas Atmospheres, all metal surfaces can be treated to prevent undesirable effects or to produce surface conditions as required.

FOR PREPARED GAS ATMOSPHERE COMPOSITIONS, COSTS, AND DETAILS OF APPLICATIONS

urite for booklet, "The Science of Gas Chemistry for Heat Treating" Form SC-129.



SURFACE COMBUSTION CORPORATION . TOLEDO 1, OHIO

DIE LIFE

INCREASED

400%

Heating for forging 1° stainless bex-bead machine bolt blanks with 10,000 cycle TOCCO Induction Heating Unit. Photo — courtesy The H. M. Harper Co.

with TOCCO' Induction Heating

• Naval Bronze, Silicon Bronze, Copper, Aluminum, Monel and all types of stainless steel are heated for forging at the H. M. Harper Co., Morton Grove, Illinois. Regardless of material TOCCO can be profitably applied to brazing, heat-treating and forging operations in almost any metal-working plant.

PRODUCTION UP—In addition to the very important savings in forging dies, TOCCO has increased production to as much as 265% of output possible with former heating methods. On the 1" type 303 Stainless machine bolt blanks

shown here TOCCO upped production from 75 to 200 parts per hour, using 35 K.W., 10,000 cycles.

VERSATILE - The same TOCCO machine is used on stock of %" to 1\%" diameter; heated zones vary from \%" to 4". TOCCO'S automatic timing cycles provide complete uniformity of heating throughout both length and cross section—assuring a uniformly high quality product.

Why not have a TOCCO Engineer investigate your plant to determine where TOCCO can cut your costs and streamline your production?

THE OHIO CRANKSHAFT COMPANY

NEW FREE
BULLETIN

THE OHIO CRANKSHAFT CO.
Days. R-4, Claveland 1, Ohio
Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

Name
Position
Company
Address
City
Zone
State

/\ | R()|B|E DESEGATIZED

High-Carb. Die Steels



There is an "mystery" to the extra toughness of DESEGATIZED' Brand Steels . . FULL STRUCTURAL UNIFORMITY is the reason for this important added quality . . FULL STRUCTURAL UNIFORMITY is available in Latrobe DESEGATIZED Brand Steels because these steels are the only tool steels produced today consistently free from harmful carbide segregation, a property which robs uniformity from average tool steels.

LATROBE, PENNA.



representative. Sales engineers stand ready to give you the important facts on Latrobe Desegatized Brand Steels.



Parts Plant Saves Approximately \$60 Daily with Homocarb Heat Treatment

Savings of approximately \$60.00 per day, or about \$22,500.00 in 18 months, followed the adoption of the Homocarb Carburizing process by the Pawtucket Spinning Ring Company, Subsidiary of Saco-Lowell



Note small space required for these 3 Homocarbs and quench. Equipment's compactness and clean operation often leads users to put it directly in the production line.

Shops of Biddeford, Maine. Most of the savings come from elimination of rejections due to distortion, these rejections being previously of no value.

Additional savings are realized because of the small amount of time required to load rings into the Homocarb plus the reduced cost per pound over pack carburizing.

In the Homocarb process, the four factors which determine the success of the carburizing treatment are under perfect control at all times. Each piece of material in the furnace is exposed to the same quality and quantity of gas, for any desired temperature and length of time. Because of this identical treatment, a uniform case results, which can be duplicated by any heat treater, day after day.

Adoption of the Homocarb process has resulted in hundreds of plants in lower operating costs and a consistently uniform product. There is a Homocarb furnace to fit your operation. For further information, write for Catalog T-623, or if your problem is specific, an L&N engineer will be glad to call. Leeds & Northrup Company, 4927 Stenton Avenue, Philadelphia 44, Pa.



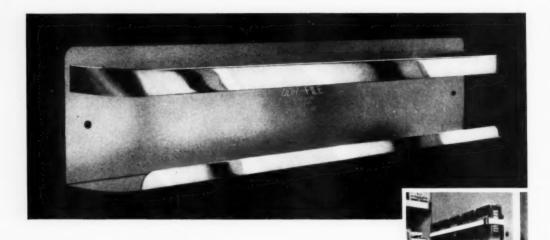
MEASURING INSTRUMENTS . TELEMETERS . AUTOMATIC CONTROLS . HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad T-623 (30

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Why you should know about this product

It's a spice rack that fastens to the back of a cabinet door. But more than that—it's an example of how you may improve your product—or increase sales—with the help of your Kaiser Aluminum Distributor.

L. M. Hobson of Portland, Oregon, designed the rack, named it the Dor-File, and began producing it by hand in 1947. A Kaiser Aluminum Distributor gave him technical advice, helped him improve fabrication methods. Today Mr. Hobson's Dor-File Manufacturing Company is turning out aluminum racks on a production line for nation-wide distribution, at the rate of 1,020,000 units per year!

If you're busy trying to perfect a new product—or improve an old one—may we suggest you consult your nearby Kaiser Aluminum Distributor. He is eager to offer you the kind of service and engineering help that established his organization as one of the country's finest materials suppliers.

Take advantage of his service. Write down the name and telephone number of your nearest Kaiser Aluminum Distributor right now. You'll find him listed below.

Permanente Metals

-

Kaiser Aluminum

FOR WAREHOUSE QUANTITIES, CALL YOUR LOCAL KAISER ALUMINUM DISTRIBUTOR

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The Hill-Chase Steel Company
of Maryland
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Peabody 7300

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LOS ANGELES, Celifornia Permanente Products Company Warehouse Division 551 East Macy Street Mutual 7286

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Rutherford 2-8100
NEW YORK: Chelsea 3-4455
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3225 Como S.E. • Gladstone 5943

OAKLAND, Culifornia

Gilmore Steel & Supply Company
1960 Cypress • Glencourt 1-1680

1960 Cypress * Glencourt 1-1680 Permanente Cement Company 1924 Broadway * Twin. 3-4600 (Handles Territory of Hawaii) OMAHA, Nebrasko

Gate City Steel Works
11th & Seward • Atlantic 1830

PHILADELPHIA, Pennsylvania Hill-Chase & Company, Inc. Trenton Ave. & Ontario St. Delaware 6-5400

PHOENIX, Arizena Arizona Hardware Co. 47 E. Jackson St. * Phone 3-3111 PORTLAND, Oregen
Eagle Metals Company
809 Dekum Building
Atwater 4962

SAN FRANCISCO, California Clingan & Fortier, Ioc. 1526 Walloce Street Mission 7-0206 Gilmore Steel & Supply Company 840 Brannan Street Klondike 2-0511

SEATTLE, Washington
Eagle Metals Company
3628 East Marginal Way
Eliot 4764

SPOKANE, Washington Eagle Metals Company E. 41 Gray Street Main 2419

WICHITA, Kansas General Metals Mfg. Co., Inc. 218-220 South Wichita 3-4314, 3-2373

pick and shovel days are over

Bull-dozers and steam shovels ended pick and shovel methods in earth moving. So modern strip mill facilities banished pick and shovel techniques in rolling stainless sheet and strip. Climaxing this progress, CRUCIBLE, a specialty steel producer for half a century, has built an \$18,000,000 mill at Midland Works specifically for rolling stainless steel—the first mill that has ever been built to take complete advantage of the best in stainless rolling practice.

You would expect this of CRUCIBLE. You would expect that the top organization in the specialty product field would make stainless as a specialty—and you would be right. Here at Midland, hot and cold rolled stainless sheet and strip are made in widths from ½" to 50" inclusive, in all gauges, grades and finishes, with the same precise quality control that has made CRUCIBLE the leader in special service steels for generations.

built to oractice. that the stainless hot and hs from with the

for
stainless
sheet
and strip

Moreover, with Trent Tube Co. joining the organization you can now turn to CRUCIBLE for every type of stainless—sheets, plates, strip, bars, tubing, forgings, wire and castings. Data sheets are available for all grades. Your inquiries will have prompt attention.

CRUCIBLE STEEL COMPANY OF AMERICA

405 Lexington Ave., New York 17, N.Y.

Branches, Warehouses and Distributors in Principal Cities



CRUCIBLE

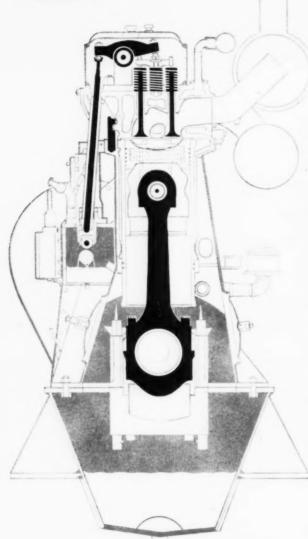
first name in special purpose steels

hot and cold rolled

STAINLESS SHEET AND STRIP

STAINLESS . HIGH SPEED . TOOL . ALLOY . MACHINERY . SPECIAL PURPOSE . STEELS

inside diesel dependability



The diesel engine parts emphasized in the cutaway drawing are usually made from alloy steels. They are the rods, pins, bolts, springs, rockers, and valves that are largely responsible for the dependability and efficiency of modern diesel power.

In many of these parts alloy steel provides the added strength to take the higher stresses encountered in this type of engine. In other parts it furnishes the increased resistance to corrosion, to heat, and to wear, needed for long trouble-free operation.

Bethlehem produces the high-grade alloy steels used for diesel parts by many of the nation's leading engine builders. From start to finish, the uniformity and quality of Bethlehem alloy steels are rigidly controlled. Every known precaution is taken to see that they meet the exacting requirements of the industry.

In addition to manufacturing the full range of AISI steels Bethlehem also provides metallurgical assistance to diesel builders. Our metallurgists are glad to help with any problems concerning analysis, heat-treatment, forging or machining.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

Export Distributor: Bethlehem Steel Export Corporation



BETHLEHEM ALLOY STEELS

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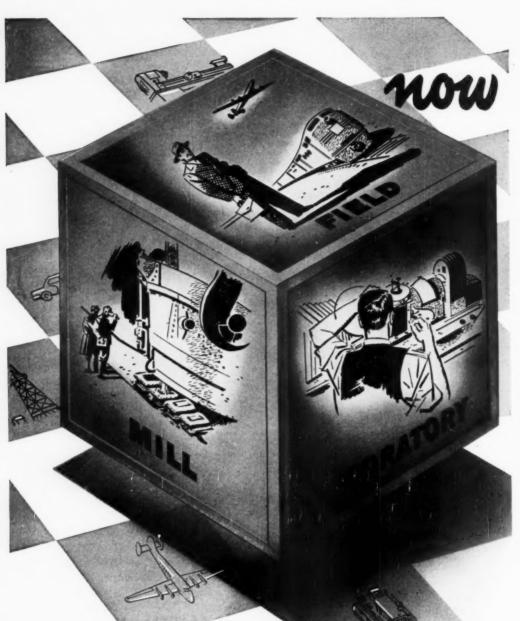




Your production line is your profit line—safeguard it by using APEX Z-50, a proven quality alloy. Having uniform casting characteristics with better-than-average mechanical properties, and free machinability, APEX Z-50 will meet most of your casting requirements. When quality plus economy is paramount, specify APEX Z-50—"Proved Best By Test"!

Apex Smelting Company

Chicago . Cleveland



REPUBLICS 3 DIMENSION Metallurgical Service

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it's Your Move!



REPUBLIC'S 3-Dimension Metallurgical Service May Uncover Your Answer to Production Speed-Up — Improved Quality— and Lower Costs!

Unless you are completely satisfied with your product on these three counts: (1) rate of output; (2) quality; and (3) cost of production, your next move in the approaching battle for business should be a complete check-up on the alloy steels best suited to your product, to your processing methods and to your equipment.

In industry after industry, REPUBLIC'S 3-Dimension Metallurgical Service has been matching the correct alloy steel to specific applications for years. Invariably, this problem has been 3-dimensional, too—requiring full consideration for: (1) the effectiveness of the steel and what it can do for the product; (2) the processing necessary to obtain desired results; and (3) the cost of the steel itself.

Here's how this service works: A Republic Field Metallurgist, together with your own metallurgists and engineers, studies your problem right in your plant under actual operating conditions. His work then is complemented by and coordinated with that of Republic's Mill Metallurgists and Laboratory Metallurgists.

The Result: Just the steel you need for every application—quality and salability for your product—high productive efficiency—low unit costs. In other words . . . the most you can get for your money.

Are you wondering what alloy steels can do for you - or if you now are using them correctly? Ask the men who know - ask REPUBLIC!

REPUBLIC STEEL CORPORATION - Alloy Steel Division, Massillon, Ohio
General Offices, Cleveland 1, Ohio

Expert Department: Chrysler Building, New York 17, N. Y.

to assist you!



ALLOY STEELS

DOWN THE LINE ...



WISSCO METAL CONVEYOR BELTS
ARE BEING USED IN:

Annealing Ovens
Baking Ovens
Brazing Furnaces
Canning
Ceramic Products
Chemical Processing

Decorating Glass
Dehydrating Food
Degreasing
Frozen Foods
Hardening Furnaces
Infra-Red Drying

Wissco Metal Conveyor Belts embody a combination of advantages that mean reduced handling costs, uniform quality and increased production efficiency for you. Designed for use in innumerable industrial applications, each Wissco Belt has over fifty years of sound engineering experience behind it.

Whether your processing operations require conveyor belts that stand up under terrific heat, or under the punishment of chemical or wet processing, Wissco woven wire belts offer you these cost-cutting advantages:

Open Weave Construction—Permitting free air circulation. Free drainage.

Extreme Flexibility—Belts will operate over small diameter pulleys.

Adaptability—Built to withstand corrosion, abrasion, freezing or brazing temperatures.

Simplicity of Design—Easily made endless; readily repaired in case of accidental damage.

Minimum Operating Costs—Greatest load carrying capacity per unit of weight and low thermal capacity means fuel economy.

If you have a conveyor belt problem, we will be glad to cooperate in its solution. Send for our illustrated booklet on types and applications of conveyor belts.

WISSCO METAL CO

METAL CONVEYOR BELTS

A PRODUCT OF WICKWIRE SPENCER STEEL DIVISION OF THE COLORADO FUEL AND IRON CORPORATION

Belt Sales Office and Plant -- \$6 Sterling \$1., Clinten, Mass. • Executive Office -- \$00 Fifth Avenue, New York 18, N. Y. Sales Offices -- Boston • Buffalo • Chathanooga • Chicago • Detroit • Deriver • New York • Philadelphia Pacific Coard Subsidiary -- The California Wire Cloth Corp., Oakland 6, California



NICHROME*V

"heat-powers" the largest continuous strip annealing lines in the world

Here are the fare targuest continuous strip annealing lines in the world—provided in stro-modern, electrically heated vertical strip furnices built by the Drever Company, of Philadelphia, Pa., for Cornegie-Itlinois Steel Corporation's Vandergrift Plant.

Each furnace is rated 1920-KW, and its multi-pass annealing line is equipped with 1.5 heating, failting and slow cooling zones for atmosphere atmosphere at temperatures up to 2000°F. Strip speed can be varied from 30°ts 200 feet per stimule. These very degree of heat treatment, through variations of temperature and time, is obtainable.

When annualed, strip is delivered to calling equipment absolutely flat—from edge to edge—to that calls are built up accurately, dense and "aguara". Up to 10 tons of 42" silicon steel strip per hour can be handled thus by each furness.

The importance of avoiding delays risconstated by repair or replacement, in an installation of this size and scope, cannot be exaggerated. Furnace "downtime" quickly drives up production costs, wipes out profits. For the milimportant, punishment absorbing heating elements, therefore, the Draver Company has specified Michrome V, recognized as the world's most dependable resistance material for heating devices.

The exceptional uniformity of Michaeme V assures precision heat control furnaves and the outstending obility of this bigb best- and corrosion-resistant alloy to retain in physical and plactical properties at elevated temperatures trouble-free operation, led the ... reduced best boar costs.

Nichrome is not only available as electrical resister meterial for heating elements, but also in call forms comprising a complete line of heat-treating equipment, from furnace parts to carburizing retorts and milites. Send to your specifications. We'll gladly make recommendations.



The complete line of each of these Drever furnaces consists of two uncoilers for honding cold reduced coils; multiple seam welder; continuous strip cleaner; looping pit to secure accurate guiding and tensioning; 13 zone controlled-atmosphere anneoling furnace, with cooling tower, drive bridle for forwarding strip; guided and controlled tensioning for recoiling; 2 recoilers.



Nichrome V Strip, $1\frac{1}{2}$ " wide x $\frac{1}{2}$ " thick, is looped as indicated to form heating elements.

* Nichrome is manufactured only by

Driver-Harris Company

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle



*T.M. Reg.U.S.Pat.Off.



Foundry Production Operations at HUNT-SPILLER MANUFACTURING CORPORATION Emphasize Economy of GAS

EFFICIENT UTILIZATION of GAS in four modern ovens resulted in a 50% saving in fuel cost when compared with previous core-baking methods at Hunt-Spiller's foundries.

This pioneer South Boston producer supplies iron, steel, and alloy castings to manufacturers of locomotive, marine, and diesel power plants. The highest quality controls are applied to this type of work, and operating economies are vital factors.

Works Manager H. E. Barber, Jr., in commenting

on the Gas-fired core-baking ovens, stated "They turn out cores that are uniform in quality, thereby reducing rejections later on in the foundry. Working conditions are much improved due to the use of a clean fuel and work-saving more than justifies the cost."

This example of the effective utilization of GAS in foundry productioneering is typical of the results to be obtained with modern Gas Equipment. Some of the important advantages of GAS in

Hunt-Spiller's core-rooms can be itemized—

- Reduction in core-baking time
- Greater uniformity of baked cores
- Improved working conditions
- Automatic control of baking temperature
- · Economy of fuel effectively utilized

Results like these are worth investigating because you'll find modern Gas Equipment for every type of core-baking requirement. It pays to keep an eye on development in Gas-fired Foundry Equipment.

Operators load one of the four modern Gas-fired core-baking ovens.



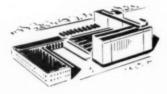
AMERICAN GAS ASSOCIATION

420 LEXINGTON AVENUE, NEW YORK 17, N.Y.

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Buy screw machine parts from Alcoa— the men who know the metal best



Complete facilities under one roof

Alcoa Aluminum screw machine parts give you strength with light weight, close tolerances where required, added sales appeal for your product.

Aluminum screw machine parts made by Alcoa give you even more: the know-how of the organization that pioneered aluminum in automatic screw machines; aluminum-trained experts who offer engineering, alloy choice and finish selection counsel—at no added cost to you.

You get all these plus competitive prices and dependable delivery.

Your Alcoa sales representative will be glad to give you complete information on our capacity, and a prompt quotation. Or write ALUMINUM COMPANY OF AMERICA, 2101 H Gulf Bldg., Pittsburgh 19, Pennsylvania.

ALCOA ALUMINUM

REW MACHINE

INGOT - SHEET & PLATE - SHAPES, RULLED & EXTRUDED - WIRE - ROD - BAR - TUDING - PIPE - SAND, DIE & PERMANENT MOLD CASTINGS - FORGINGS - IMPACT EXTRUSIONS ELECTRICAL CONDUCTORS - SCREW MACHINE PRODUCTS - FABRICATED PRODUCTS - FASTENERS - FOIL - ALUMINUM PIGMENTS - MACHESIUM PRODUCTS

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The New Type O56-PT incorporates all the revolutionary new features of Hevi Duty Laboratory Furnace Design.

Two months ago, we introduced a new standard small size Muffle Furnace, type 051-PT, housed in a cylindrical shell and containing vastly improved features. Now we are ready with the second in the series, Type 056-PT, with inside measurements of $7\frac{1}{2}$ " x 14" x $5\frac{1}{4}$ ". Research engineers will find it ideal for all general laboratory requirements such

as drying of precipitates, ash determinations, fusions, ignitions, heating metals and alloys, enameling, heat treating, and experimental test work.

Six of many important features are listed below. For complete specifications and details write for the new Bulletin LAB-849.

ELECTRIC COMPANY ideal for all general laboratory requirements such LABORATORY FURNACES MULTIPLE UNIT SLECTRIC EXCLUSIVELY HEVI See your Laboratory Supply Dealer or Send for Bulletin LAB-849. MILWAUKEE 1, WISCONSIN Instruments and Con-As a result of correct Reversible and easily 36 steps of control Controls are mounted Removing rear panel through a Hevi Duty Tap-Changing Trans-former allow maxireplaceable Multiple Units, time-tested for trais operate at apinsulation design, you in a recessed position exposes terminal board. can shift rapidly to preximately room for safety and at cor-Releasing front panel temperature . . . there is no trapped heat. desired operating 30 years, have been rect angle for proper permits control assembly vision for operator. to slide forward. temperatures. retnined. mum flexibility.

Greater ease in use accompanies products made lighter with Dow

1/15/1/12/5/11

the world's lightest structural metal!

Simplify Product Design-Speed Production and Assembly ... with Magnesium

Leading manufacturers of materials handling equipment are wisely using magnesium wherever they can. They've found that magnesium is as versatile and workable as it is light. Magnesium extrusions is as versatile and workanic as it is light. Magnesium extrusions streamline design and production because they are available in an almost unlimited variety of shapes. Magnesium sand castings provide good strength, shock resistance and ease of machining. Magnesium sheet is strong without being heavy and is readily fabricated by well-

If your product is designed to save manpower, one metal, Magnesium, deserves your first consideration.

Magnesium is the world's lightest structural metal. It gives materials handling equipment new found lightness because it is a full one-third lighter than any other light metal. Hand trucks, dockboards, conveyors and countless other products become easier to lift and move-easier to sell-with magnesium. And this bonus-this premium of lightness-can be

> had without sacrificing strength, rigidity and durability because parts made from magnesium are sturdy and long lasting. Give your product the all-important selling advantage of noticeably greater ease in use-switch to magnesium. Write for a free copy of "How Magnesium Pays" a book filled with actual case studies of succe sful magnesium applications.

> THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN
> New York • Boston • Philadelphia • Washington • Cleve and
> Detroit • Chicage • St. Louis • Houston • San Francisco
> Los Angelos • Seettle
> Dow Chemical of Canada, Limited, Toronto, Canada



Lighter Products Sell - make your product Magnesium Light

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that's most machinable...

Gray Iron Characteristics Include:

Castability
Rigidity
Low Notch Sensitivity
Wear Resistance
Heat Resistance
Corrosion Resistance
MACHINABILITY
Vibration Absorption

Durability
Wide Strength Range

Machinability is one of the most important advantages of Gray Iron. Thousands of products, from tiny instrument parts to massive machinery castings, attest to this fact.

Because of its composition and structure, Gray Iron machines easily. The graphite in the iron acts as a lubricant and aids in short chip formation. It can be ground, honed or polished to mirror-like finishes. It is possible to machine Gray Iron castings, then heat-treat to harden and polish to obtain a higher degree of wear resistance.

Are you taking full advantage of the unmatched combination of properties found in Gray Iron . . . plus its ultimate economy?

Write for free booklet, "GRAY IRON—Its Mechanical and Engineering Characteristics, and Details for Designing Cast Components".

Make It Better with Gray Iron Second largest industry in the metalworking field

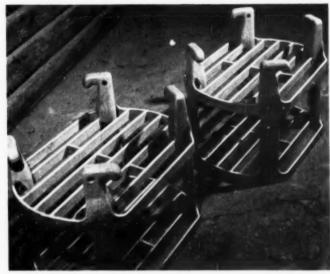


GRAY IRON FOUNDERS' SOCIETY, INC.

NATIONAL CITY-E. 6th BLDG., CLEVELAND 14. OHIO

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ACCOLOY CASTINGS that incorporate



ENGINEERING DESIGN AND INGENUITY

The above photo illustrates a special fixture designed for a pit-type furnace, 25" x 36", to carburize mowing machine knife heads for a large farm implement manufacturer.

From our engineering department came designs which provided maximum loading with a minimum of alloy weight—increased furnace production—unobstructed gas circulation—uniform quenching and minimum distortion.

Note the uniformity of sections throughout entire casting with special tubular lifting eyes as an integral part of the fixture to facilitate handling.

Quality castings, in which sound engineering fundamentals are incorporated, plus—quality control from pattern to finished casting and engineered foundry technique—offer our customers greater savings in operating costs.



ALLOY ENGINEERING & CASTING CO.

Alloy Casting Co. (Division)

Champaign, Illinois

ENGINEERING OFFICES IN PRINCIPAL CITIES

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Sometimes
it costs less
to use Steel
that costs more!

Here, U·S·S COR-TEN used cuts weight 18%

* The bigger the tank the bigger the saving In the 42" x 10" Stonesteel tanks under construction above. In the 42" × 10" Stonesteel tanks under construction above, the use of Cort Ten reduces lighter Cort Ten tanks were on material cost. When these lighter Cort Ten tanks were shipped to a housing development in Norfolk. Va. this was the store that the same tendence were \$9.84 less, bringing the total savings per tank to \$14.84.

in place of carbon steel cuts material cost 10.8%

cuts shipping cost 16%

During the past 12 years, U·S·S Con-Ten-the pioneer high strength steel-has earned a world-wide reputation for reducing costs by reducing weight in freight cars, buses, trucks and other mobile equipment. That's exactly what Con-Ten was developed for, so we were not surprised.

But here is the story of a money-saving application, far outside the transportation field, that aptly illustrates how stationary equipment of many kinds can be built advantageously of U·S·S COR-TEN in place of carbon steel-not only to improve the product but to reduce its cost.

SEVERAL years ago the Cemline Corporation of Cheswick, Pa., developed a hot water storage tank designed to prolong life even in those areas where water supplies are unusually corrosive. A special hydraulic cement lining that prevents corrosion by eliminating any corrosive water-to-metal contact did the trick. But in solving the corrosion problem the cement lining created another. Its substantial weight when added to the weight of the heavy carbon steel shell resulted in a unit that was unwieldy to handle and difficult and costly to install.

A lighter tank was definitely called for. This need was emphasized with every increase in freight rates, and as more and more tanks were shipped to distant markets. The question was, how to reduce weight and still meet high strength requirements. Cemline engineers found the answer in U-S-S COR-TEN.

Due to the protective lining, interior corrosion could be disregarded, so they were able to take full advantage of U-S-S Cox-Tex's high yield point (50,000 psi.) and to use it in gages 40% lighter than the carbon steel gages previously required. This 40% reduction in cylinder weight reduced the total tank weight 18%.

These weight savings resulted in cost savings all along the line. Cost of the steel per cylinder was 10.8% less (because the weight saved more than offsets Cor-Ten's slightly higher cost). The lighter tanks were handled with less trouble and less expense. And, freight charges on every shipment—on steel from the mill, on the tanks

to the customer-were reduced almost 16%.

To show what this means in actual dollars and cents savings, take the case of the 45-gallon Stonesteel tank (shown at right) produced by the thousands for residential use. Replacing the carbon steel shell, .138" thick, with U-S-S Cox-Tex .0828" thick, reduced weight 42 lb., cut steel cost 35 cents. When these tanks were shipped to Richmond, Va., freight charges were 72 cents less for the lighter tanks, making a total saving per tank of \$1.07.*

"U-S-S Cor-Ten," says the President of Cemline Corporation, "does more than reduce our costs. Because of its stiffness it forms more smoothly on our bending rolls, and fluting difficulties formerly experienced have disappeared. In welding, too, Cor-Tex behaves better than straight carbon steel. It does not seem to burn away so readily under the arc and thus makes welding easier and faster. We know our customers have less trouble and less expense handling these lighter Cor-Tex tanks. And because Cor-Tex has from 4 to 6 times greater atmospheric corrosion resistance we have every reason to believe that Stonesteel tanks made of U-S-S Cor-Tex are much less likely to rust when exposed to external condensation, when

leaky fittings drip or when the enameled surface is damaged in shipping or installation. That's why, for all our tanks, except where codes require flange steel construction, we've standardized on U.S.S. Con-Tex."



AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: (LEVELAND, ONIO CARNEGIE-ILLINOIS STEEL CORPORATION, PITTSBURGH & CHICAGO
COLUMBIA STEEL COMPANY, SAN FRANCISCO - NATIONAL TUBE COMPANY, PITTSBURGH TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM UNITED STATES STEEL SUPPLY COMPANY, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST UNITED STATES STATES STEEL EXPORT COMPANY, NEW YORK

U·S·S HIGH STRENGTH STEELS

U-S-S COR-TEN . U-S-S MAN-TEN . U-S-S MANGANESE-NICKEL-COPPER

Room 20	988 Carn e send m	egie B	building	bookl	sheidiaries tehurgh 30, et showing ing Stoness	how U-S-S
Pleas		High	Stre	ngth S	teel repres	entative call
Name						
Position						
Compan	y					

Zone State

UNITED STATES STEEL

9t's MISCO for HEAT RESISTING ALLOYS IN ROLLED MILL FORMS

Sheets — Plates — Rounds O Squares Hexagons Flats — Angles Channels Sections Pipe O Nuts O Welding Rod



MISCO Rolled Mill Forms are Stocked in These Metals

These Misco Alloys insure a correct alloy analysis for most conditions of high temperature service from 1400 to 2100 F.

MISCO METAL—36 Nickel 16 Chromium—Type 330

MISCO K-25 Chromium 20 Nickel-Type 310

MISCO B—23 Chromium 14 Nickel—Type 309 Make use of our big warehouse stocks of Misco Rolled Alloys for construction of heat resistant equipment like this. We have over 200 items of rolled mill forms ready for immediate shipment. For high quality heat resisting alloys — send your orders to Misco. Telephone Lorain 7-1545.

Keep informed on available stocks of Misco Rolled Mill Forms, Send for current lists.

ROLLED PRODUCTS DIVISION Michigan Steel Casting Company



One of the World's Pioneer Producers and Distributors of Heat and Corresion Resisting Alloys
1998 GUOIN STREET • DETROIT 7, MICHIGAN

Liquid carburizing, plus martempering



- A MINIMALYSE DETRICATION
- REDUCES FINAL
- . ASSURES UNIFORM CAS
 - PRODUCES TOUGHER
 - CORE
- PREVENTS CRACKS AND
- . ELMINATES SKILLED
- LABOR
- . SPEEDS PRODUCTION
- . LOWERS MAINTENANCE
- COSTS

... with first cost of equipment at least 50% less



Unretouched macrograph of crank-shaft heat treated in above installation. Note uniformity of .040 inchese. Carburized at 1760° F. for 2 hours; stabilized in a neutral bath at 1450° F. for 6 minutes followed immediately by an isothermal quench in a nitrate bath at 400° F., air cooled and then drawn at 450° F. The complete heat treatment including a final wash is accomplished in slightly over 5 hours. Total distortion of the crankshaft is held within .005 inch.

First to utilize the electrode type furnace for liquid carburizing, Ajax was also first to realize the advantages of combining this process with a martempering or austempering treatment, Results from commercial installations in operation for 2 years have fully justified the predictions made for this dual process.

Work is immersed in a liquid carburizing or cyanide hardening bath, where the desired case is produced. It is then transferred to a neutral salt bath maintained just above the upper critical temperature of the case, and followed directly by an isothermal quench. Toughness is thus added to the core while assuring a uniform, hard case. The entire operation is carried out with one heating of the work.

Write for Ajax Bulletin 120.

AJAX ELECTRIC COMPANY, INC.

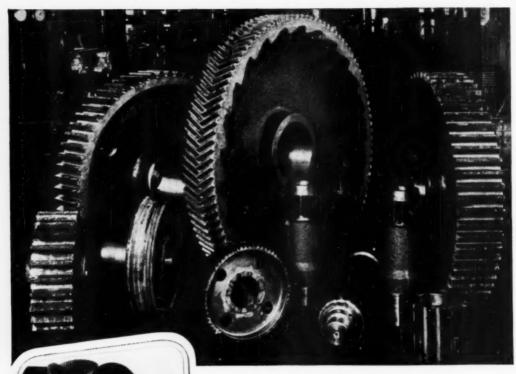
910 Frankford Avenue, Philadelphia 23, Pa.

The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively

In Canada: Canadian General Electric Co., Ltd., Toronto, Ont. Associate Companies: Ajax Metal Co., Ajax Electric Furnace Corp., Ajax Electrothermic Corp., Ajax Engineering Corp.



HUTTGREN ELECTRIC SALT BATH FURNACES



we tabulate below the physical properties of the surface and care values of SAE-1020, SAE-2315, Steels, Carburized or Case Hardaned with "NELOY" and "NELOY-MOLY" Steels Normalized or Liquid Quenched, Finish Machined and Fleme Hardaned.

- 1		Ultimate Tensile Lie per Sq. In.	Elaste Limit or Yold Point Lis per Sq. In	Flongation Percent	Reduction of Area Percent	Brosell	Seleto- scope
_	S.A.E. 1020 Case Hardened (Surface) S.A.E. 1020 Case Hardened (Core) Neloy Annealed and Flame Hardened	260/300,000	180/195,000 30/ 35,000	5-10 30-35	8-12 40-50	314-601 120-140	71 81 17-20
	Treatment 10B (Surface)	218/270,900	190/240,000	8-12	20-35	477-590	66 30
_	Treatment 10B (Core)	85/ 90,000	95/65,000	23-40	30-40	163-179	23 24
_	S.A.E. 1020 Case Hardened (Surface) S.A.E. 1020 Case Hardened (Core) Nelov Heat-treatments No. 3 and 10B	260/300,000 60/ 70,000	180/195,000 30/ 35,000	5-10 30-35	8-12 40-50	514-601 120-140	21-81 17-20
=	(Surface). Nelov Heat-treatments No. 3 and 10B (Core).	220/210.000	200/240,000	8-12 20-26	20-35 40-50	550-590 202-240	68-80
_	S.A.E. 2315 Case Hardened (Surface)	290/329,000 (112/129,000)	185/205,000 99/120,000	4- 8 12-20	6-10 38-51	570-653 249-275	78-87 35-39
	Drawn and Flame Hardened (Surface) Nelox-Molybdenum, Normalized,	258/281,000	212/217,000	6-10	8-12	514-555	71-75
-,	Drawn and Flame Hardened (Core)	90/110.000		-	30-40	190-220	28-33
_	S.A.E. 2315 Case Hardened (Surface) S.A.E. 2315 Case Hardened (Core) Nelox-Molybdenum Heat-treatments	290/329,000	185/205,000	4-8 12-20	6-10 38-31	370-651 249-275	78-87 35-39
=	3A and IOB Flame Hardened (Surface) Nelos-Molybdenum Heat-treatments		217/265,000	4-8	6-10	555-627	75-84
	3A and 10B Flame Hardened (Core)	(132/150,000)	120/135,000	10-18	25-35	290-320	11 15

*The variation in tensile and yield in the third table is due to the alloyed elements of 2315 which is a nickel steel. This produces a higher physical on a straight annealed steel compared with more economical alloy used in Neloy Mole.



CRANE GEARS



NATIONAL ERIE CORPORATION
ERIE, PENNSYLVANIA - U. S. A.





You can be SURE.. IF IT'S Westinghouse

One Package...One Responsibility

FROM the smallest job to the largest, seven elements enter into every RF HEATING application.

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EQUIPMENT - Coordinated to your problem, built and tested for your specific needs;



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the equipment on the job; and Westinghouse emergency field service when needed!

Westinghouse supplies all seven elements for your application. Call your local Westinghouse representative for full details, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.





America Needs '49ers

JUST a hundred years ago, the Forty-niners stormed the gold fields of California. They faced staggering obstacles, sure hardship, uncertain reward. Thousands failed, thousands of others realized modest gain, a few made fortunes. None sought or received help or direction from a benevolent government.

Now a century later, America faces another age of golden opportunity -- an

era when science and industry reveal new treasure to be had for the making. Turning today's visions into reality calls for '49ers-men of purpose and resolution, courage and independent spirit. You as a leader in your community may find a personal challenge and an inspiration in the Old '49er. By example and precept, you can help America toward her greatest accomplishments--in prosperity and peace.

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Metal Progress: Page 156

How does your cleaning time compare?



Castings 24 Times Faster for Oil Well Supply Co. of Dallas, Texas

to clean most effectively at lowest cost per hour of operation. It directs all the abra-sive on a given target with highest velocity for a given peripheral speed . . . cleans faster, better, cheaper.

CLEANS FASTER because it throws a greater volume of abrasive, covers a larger area with greater density.

CLEANS BETTER because it produces a finer finish than possible with old-style methods.

CLEANS CHEAPER because it requires less horsepower to propel abrasive with velocity and quantity equal to any other method . . . uses less manpower . . . minimizes maintenance . . . eliminates air compressor investments.

The right Pangborn Machine equipped with ROTOBLAST gives top blast cleaning efficiency.

Look to Pangborn for the latest developments in Blast Cleaning and Dust Control Equipment!

HERE IS THE PROOF! In 1948, the Oil Well Supply Co. of Dallas, Texas, installed this 21 cubic foot Pangborn ROTOBLAST Barrel to replace five conventional tumbling mills at its Imperial Works in Oil City, Pa. The results are amazing! The ROTOBLAST Barrel cleans two tons of medium size castings in 15 to 20 minutes, as compared to 6 to 8 hours with the older equipment. That's 24 times faster or a saving of 95.8% on cleaning time alone!

ROTOBLAST* Cleans

A year's operation showed additional savings . . . fewer hours expended because ROTOBLAST cleans entire normal foundry output of small and medium castings in five hours . . . castings with hard-to-reach pockets are completely cleaned . . . machining is easier and cheaper because ROTOBLAST removes all sand and scale . . . abrasive costs are lower because abrasive recovery unit reclaims all usable shot!

HIND OUT ABOUT YOUR PLANT! No matter what kind of castings you turn out, whether you operate a specialty or jobbing foundry, there's a Pangborn ROTOBLAST Table, Barrel, or Table-Room designed to bring you amazing savings like this! Bulletin 214 gives all the facts, use handy coupon to get your free copy. Address: PANGBORN

CORPORATION, 1404 Pangborn Boulevard, Hagerstown, Md.

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with the right equipment for every job

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Please send me a free copy of Bulletin 214.

Company Address





Tough is the word for Omega. It thrives on coldbattering jobs where you've got to have a tool steel with super shock-resistance. And Omega has a normal working hardness of 55 to 59 Rockwell C at cutting edges; that's hard enough to hold a sharp edge on even the severest kind of shock jobs.

Use Omega for tools like these:

Chipping chisels Core breakers
Calking tools Shear blades
Punches Beading tools
Rivet busters Swaging dies

Long a toolmakers' favorite for general-purpose shock tools and machinery parts, this fine silico-manganese steel combines ductility, toughness and hardness. There's no better steel for withstanding drastic shocks at normal temperature. It's economical; and it's easy to forge, machine, and heat-treat. Give Omega a trial, as rough as you like. The nearest Bethlehem tool steel distributor stocks it for quick delivery.

THESE PROPERTIES MEAN SHOCK-RESISTANCE

	100 (
Unnotched Charpy	
Tensile strength	340,000 psi max
Yield point	.280,000 psi max
Hardening, 1625 F, oil quench; 155	OF, water quench
Tempering	Rockwell C 59-55

BETHLEHEM STEEL COMPANY BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

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Bethlehem Steel Export Corporation



OMEGA one of Bethlehem's Fine Tool Steels

Here's what they're doing

lew technique for welding chrome pipe



YOU CAN PUT YOUR CONFIDENCE IN . . .

Using General Electric welding electrodes the Houston Pipe & Steel Co. has successfully used a new procedure for welding 4-6 chrome pipe without the usual time-consuming subsequent annealing procedure.

According to their Chief Engineer, here's how they do it: The joint is first brought up to a 600-800 F temperature using a large preheating tip with oxy-acetylene, and held at that temperature during welding. The welds are then made using G-E Type W-1502 stainless electrodes. Immediately after completing the joint, its temperature is raised to 1200-1350 F, it is wrapped in asbestos tape, and then cooled to room temperature.

Contrary to popular belief, the weld metal does not become brittle. Certified laboratory tests indicate very desirable results, including ultimate tensile strength of 73,200 psi, satisfactory 180 degree root bend, Brinnell hardness in the weld of 248 and in the pipe of 174.

"We used this procedure throughout the production of the chrome pipe," states the Chief Engineer, "and the lot was completed satisfactorily, quickly, and inexpensively."

GENERAL & ELECTRIC

with G-E Stainless Electrodes

• We've made that old bugaboo, the vertical-down weld, say "Uncle!" with a new coating formula on G-E 1000 series stainless electrodes in the ½" and smaller sizes. (The 1000 series have a limetype coating for reverse-polarity d-c welding; there are 16 standard types for welding various analyses of stainless.) Other analyses may be obtained with the new coating composition upon request.

Already endowed with excellent usability characteristics in the vertical and overhead position as well as the horizontal, their new coating makes them particularly well suited for the ordinarily troublesome vertical-down welding.

G-E stainless steel electrodes are regularly demonstrating their versatility and ability to help solve difficult welding problems. Why not investigate them; your General Electric Arc-welding Distributor carries a complete stock, also including eleven types in the 2000 series with a titania-type coating for use on either a-c or d-c.

FOR OTHER WELDING JOBS there are some 40-odd additional types of G-E electrodes including a most complete line of low-hydrogen types, cast-iron, hard-surfacing, and phosphor-bronze electrodes, as well as mild-steel and general-purpose rod for manual or machine welding. Mail the coupon now for a copy of the handy, pocket-sized G-E electrode catalog.

Vertical-down Welding MADE EASIER Stainless steel vertical-dow let made with new G-E W-1310 electrode; note the smooth, I appearance. (And if you think appearances may be deceiving. may we suggest the proof of the electrode is in the welding. He about giving them a tryl) HAVE YOU SEEN "ARC WELDING AT WORK"? This 30-minute, soundcolor motion picture depicts clearly the design and production advan tages inherent in the three basic types of arc welding. Ask your G-E Acc-welding Distributor. Mail the coupon to him, or to: Dept. G712-1, Apparatus Department General Electric Co., Schenectady 5, N.Y. Send me bulletin GES-3571, packet-sized electrode catalog. Address

ARC WELDERS · ELECTRODES

ACCESSORIES · RENEWAL PARTS



PRODUCT IMPROVEMENT

The Automotive Industry uses the SR-4 to check stresses and strains in vital parts, eliminate weaknesses, improve the product.

The testing device of a thousand uses



AIRCRAFT LIGHTENING

The Aircraft Industry uses the SR-4 to plot the complex flow of stresses in aircraft wings during flight, "balance" the design.



STRUCTURAL STRESS ANALYSIS

Engineering organizations check theoretical stress distribution against actual patterns, to verify design practice.



MACHINE REDESIGN

Equipment manufacturers use the SR-4 to isolate the cause of puzzling breakages and to point the way to a correct solution.



MASONRY STRESS DETERMINATION

The heavy construction industry is learning valuable new facts on how masonry withstands loading . . . with the SR-4.



MAKING BALLISTICS STUDIES

The flow of stress in a gun barrel as the bullet passed through was once a matter of floory... but a matter of accurate knowledge now, because of the SR-4.

BALDWIN CRA* STRAIN GAGE

It's hard to believe—yet this one little testing device, no larger than a postage stamp, has done more to broaden engineering knowledge through product analysis than all other testing equipment combined:

It has provided—for the first time—an accurate picture of actual stress distribution in such structural, equipment and machine parts as an airplane wing in flight... the interior of a mammoth masonry dam... the barrel of a cannon when the shell flashes from breech to muzzle... the frame of a punch press... the connecting tods of diesel engines during operation. In every instance, the new knowledge it revealed has permitted engineers to better the design job.

The long list of successful uses does not define the ultimate applications of the Baldwin SR-4 strain gage, but merely indicates its almost limitless possibilities. If you have any problem where unexplainable failures of parts are puzzling you . . . where some equipment must be lightened while retaining balanced strength . . . where a complete report of actual stress distribution in a structure will aid you in design . . . the Baldwin SR-4 can undoubtedly help you, as it has helped many others.

A comprehensive line of indicating, recording and switching instruments and equipment is available for both laboratory and field studies. The unitsillustrated include an SR-4 Strain Recorder Chart, and SR-4 Portable Strain Indicator, and an SR-4 Switching Unit, with which 48 strain gages can be switched in and out of service in as little as 50 seconds. These are only a few of many.

ASK FOR LITERATURE. Informative give a concise technical description of the

Technical Bulletins give a concise technical description of the SR-4 and collateral equipment. Ask for copies, indicating the type of testing in which you are interested.

The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Boston, Chicago, Cleveland, Houston, New York, Philadelphia, Pittsburgh, San Francisco, Seattle, St. Louis, Washington. In Canada: Peacock Brothers, Ltd., Montreal, Quebec.

*T. M. Reg. U. S. Pat. Off.

TESTING HEADQUARTERS

BALDWIN

Metal Progress; Page 162



for Michigan non-ferrous foundry

NE of the largest producers of propellers for outboard and inboard motors had trouble in the foundry with porous castings.

A Cities Service combustion specialist was called in for consultation. With the aid of the Cities Service Industrial Heat Prover instrument he soon found that the trouble was

due to the presence of excess air in the furnace gases and offered suggestions to correct the situation. Result: Scrap loss was reduced from 4100 to 471 lbs. and affected a saving of \$2359.

Countless cases of similar results are now on file. If your operation includes industrial furnaces and heat treating units of any size or type, you too can profit from such service. Write today for a free demonstration.

FREE! A fact-filled booklet entitled "Combustion Control for Industry" is available upon request. Write Cities Service Oil Company, Sixty Wall Tower, Room 464, New York City 5, N.Y.

CITIES 🖎 SERVICE 💳



... sets a new high of 3000 F for insulating fire brick service



 Here is a new insulating fire brick, especially developed by the Johns-Manville Research Laboratory for use in forge furnaces, ceramic kilns, chemical process furnaces and other types

of high-temperature equipment operating above the previous range of insulating fire brick.

Some of the more outstanding advantages of JM-3000 Insulating Fire Brick are: It is the highest temperature insulating fire brick made for backup or exposed use, effectively withstanding the full 3000 F. Its efficiency remains at a high level throughout the life of the brick. It has exceptional service advantages in many operations at lower temperatures where regular or special fire brick is ordinarily used.

With its combination of outstanding insulating and refractory properties, JM-3000 Insulating Fire Brick has been found to provide longer life, greater fuel economy and important savings in downtime. For further information, write to Johns-Manville, Box 290, New York 16, N. Y.

PHYSICAL AND THERMAL PROPERTIES

Molded from high quality kaolin clays plus alumina Density—63-67 lb per cu ft

Modulus of rupture-200 lb per sq in.

Linear shrinkage—(24 hr Panel test @ 3000 F) .8 per cent Linear thermal expansion to 2000 F—.5 to .6 per cent

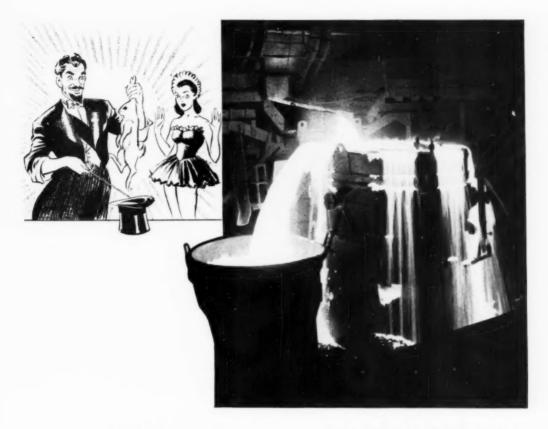
Pyrometric cone equiv.—Cone 37+ (3308 F+)

Temperature limit—3000 F

Conductivity (Btu in. per sq ft per F per hr at mean temp)
F 500 1000 1500 2000
Btu 3.10 3.20 3.35 3.60

Johns-Manville

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WHERE STEEL BECOMES A MAGIC METAL

Right here in the ladle, the Wisconsin Sulfite Process makes steel of standard specifications a metal of magic machinability. Sodium sulphite is mixed with the molten steel, "washing" non-metallic, abrasive inclusions from the metal. Here is the result . . . a steel product far more machinable with a minimum

effect upon physical properties.

If you have machining problems, it's time to consider Wisconsin Sulfite-Treated Steels. In dozens of applications, this "magic metal" has "pulled rabbits out of a hat" greatly increasing production and tool life and producing a superior machined surface.



WISCONSIN STEEL COMPANY, Affiliate of INTERNATIONAL HARVESTER COMPANY

180 North Michigan Avenue . Chicago 1, Illinois

WISCONSIN STEEL

August, 1949; Page 165



Looking For An Answer to Heat-Treat CONVEYOR TROUBLES?

If you're bothered by these conveyor troubles:

- Jumping the sprockets
- Pins "crank-shafting"
- Frequent replacement of defective links
- High maintenance cost

... you'll find such troubles can usually be traced to improper engineering or inspection of the original conveyor parts.

For example, if dimensions on individual castings are not accurate, the driving drum or sprocket will exert an unequal pull on each line of links. This causes stretching. Pins often "crank-shaft"... causing belt to "ride" on top of driving drum lugs, instead of engaging properly. This results in fracture of individual links and increased maintenance costs.

The cure for such troubles rests on careful

engineering and production. Individual castings must be identical in length—so the belt will engage properly with driving drum, and no one link will be overstressed. Good design also provides close spacing between links for carrying small parts... and allows sufficient clearance to eliminate excessive wear.

Electro-Alloys has made a specialty of the precision engineering and production techniques required to produce conveyor belts of outstanding quality. We can show you proof that THERMALLOY high alloy conveyor parts give longer life, cut downtime and maintenance costs.

Call your nearest Electro-Alloys engineer. Or write Electro-Alloys Division, 1975 Taylor Street, Elyria, Ohio.

THERMALLOY resists temperatures up to 2200° F.

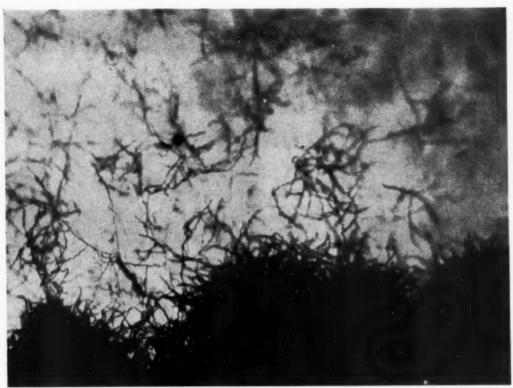
*Reg. U. S. Pat. Off.



ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO

Metal Progress; Page 166



An example of chaetomium globosum (cellulose destroying mold) magnified 76 times

There's no money in growing mold!

Mold and bacterial action can play havoc in any shop. Machine down-time goes up—production goes down—because these microorganisms cause lubricants and coolants to go "sour."

The Dowicides control such losses—reduce waste to a minimum. They increase the service life of cutting, grinding, rolling and hydraulic soluble oil emulsions. These tested materials developed by The Dow Chemical Company,

are available in both oil and water types
-ideally suited for industrial use.

Don't let your profits go "sour"—keep the bugs out! Extensive Dow laboratory facilities are devoted to assisting you with your problems. Contact the sales office nearest you.

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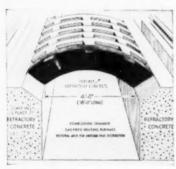




Incinerator Arch and Floor, quickly installed with Castables. No cutting, fitting, or ramming. Upkeep costs are low.



Heat-treating furnace built with Castable Refractories. Cuts heat loss . . . prevents infiltration of outside air. Gives durable service life.



Combustion chamber of Gas-fired Heating Furnace. Each section of Arch is cast in one piece with Refractory Concrete. No mortar joints. Side walls and floor cast solid.

Practically any shape you want...

* FURNACE WALLS,

* ARCHES, HEARTHS,

* DOOR LININGS,

* SPECIAL SHAPES



Quickly adaptable to any size, shape or thickness—Castable Refractories are invaluable first-aid for emergency repairs. Rapid hardening Castables are ready for service in 24 hours or less.

They're easy to use, too. Add water to the packaged mixture, cast it in a simple form or mold. Large jointless sections are as easy to cast as small special shapes. No cutting or fitting.

For walls, arches, hearths, you get a one-piece refractory that reduces heat loss, prevents infiltration of outside air. No shrinkage to bother about. High spalling resistance. Low upkeep.

You're sure of fast, adaptable construction and long, durable service when you specify a Castable Refractory made with LUMNITE cement. You get a balanced, tailor-made refractory that results from the blending of selected materials. You get suitable refractory aggregates with cold-setting, high strength binder, LUMNITE.

Castables to meet different temperature and insulation requirements are made by manufacturers of refractories and sold by their distributors. For further information, write to LUMNITE DIVISION, Universal Atlas Cement Co. (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, N. Y.

Specify CASTABLE REFRACTORIES
made with LUMNITE

MP-L-3



FOR REFRACTORY CONCRETE

NBC SUMMER SYMPHONY CONCERTS—Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—June to September

CANS

CANISTERS

CLOSURES

make them good with

Slectrolytic Tin Plate

Dry-pack containers and closures . . . cans, canisters and caps . . . if you make them of Weirite electrolytic tin plate, you can make them high in quality, low in cost. You'll find you can depend on Weirite for correct ductility, uniform thickness of coating, and accurate gauge. It's obtainable in sheets, and in coils of any desired length in widths up to 33 inches.





WEIRTON STEEL COMPANY

WEIRTON, W. VA., Sales Offices in Principal Cities

Division of NATIONAL STEEL CORPORATION, Executive Offices, Pittsburgh, Pennsylvania



Operator using the new Model No. 1506 low speed polisher. Section of laboratory equipped with No. 1251 Duo Belt Sander—No. 1700 Electro Polisher—No. 1315 Press.

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In setting up complete laboratories or adding items to present equipment the metallurgists will find in the Buehler line of coordinated equipment everything needed for producing the best work, with speed and accuracy.

Write for bulletin of new equipment or information on any specific item. We invite correspondence relative to setting up complete laboratories suitable for any particular requirement.

Exclusive U. S. agents for Amsler and Chevenard Testing Machines

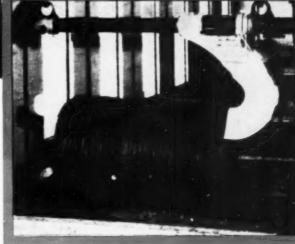
METALLURGICAL APPARATUS 165 WEST WACKER DRIVE, CHICAGO 1, ILL.







hese Before and After pictures show the results you can obtain by using Enthone Acid Addition Agent. The health of the worker is safeguarded, corrosion on surrounding buildings and finished steel is reduced, and an acid drag-out saving of twenty percent is obtained.





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ARMCO STEEL CORPORATION



Metal Progress: Page 170



The Erection Superintendent (center) of this progressive paper equipment manufacturing plant consults with a Gulf Lubrication Engineer (left) on rust prevention for dryer roll surfaces.

"All our dryers, both for foreign and domestic shipment, are treated with Gulf products to insure protection against corrosion," says this Erection Superintendent. "Some of our foreign customers have complained about competitors' rolls arriving in a rusted and pitted condition. Our erectors in the field report that all of our shipments have arrived in perfect condition, thanks to Gulf Rust Preventives."

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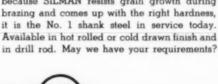
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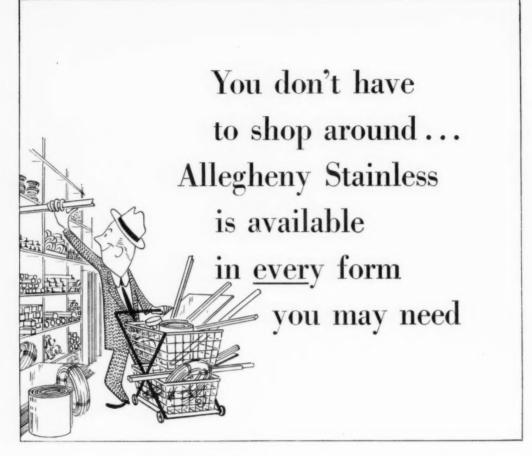


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Metal Progress; Page 176



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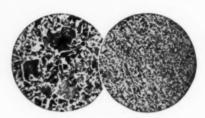
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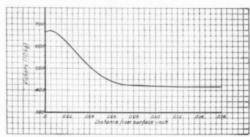
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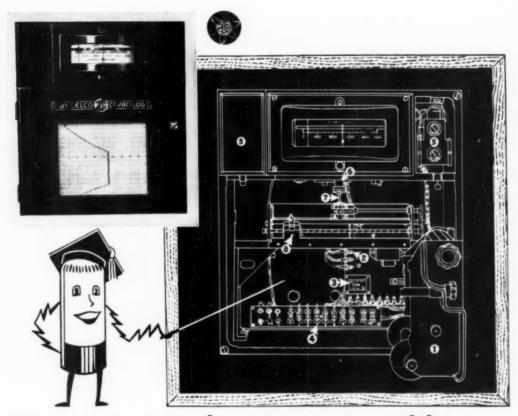
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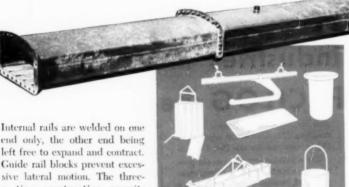
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Metal Progress

Ernest E. Thum, Editor Taylor Lyman, Associate Editor

August, 1949

Volume 56, No. 2

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Metallurgical

Laboratory

at Oak Ridge

PROBLEMS involved in the research and development of those "new" metals and alloys whose utilization is relatively unique to the atomic energy program (uranium, thorium, beryllium, zirconium, and others) have proved to be considerable. Not only are their processing and fabrication rather difficult, but investigation has been encumbered by the existence of certain radiation and chemical hazards involved in their handling. Accordingly, a modern metallurgical laboratory equipped for research in this field must not only provide wellintegrated research facilities but must also provide for adequate protection of the working personnel. The recently completed facilities of the Metallurgy Division of the Oak Ridge National Laboratory* may be considered as representative of the laboratories now being built (or planned) to cope with these problems.

A few comments pertaining to the health hazards encountered in working with the metallic materials entering into nuclear reactor design will serve to orient the reader along the line of thought leading to the final design which has been incorporated into the Oak Ridge building. Protection is required against two health hazards — first, those arising from the inhalation of dust and fumes which might cause chemical poisoning, and second, those resulting from radiation. The radiation hazards may actually be broken down into two categories depending upon the radiation level. Some

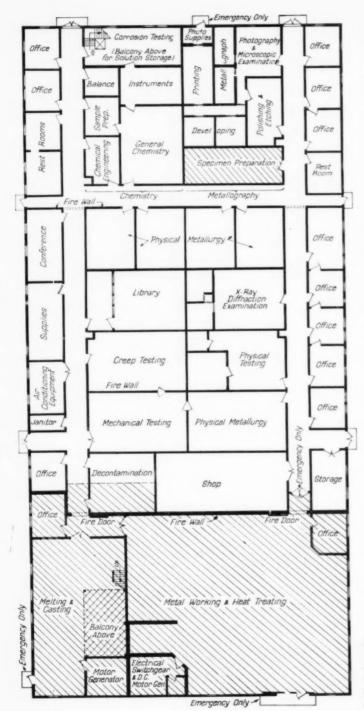
By L. K. Jetter
Staff Member
and E. E. Stansbury
Consultant
Metallurgy Division
Oak Ridge National Laboratory

materials which have been exposed to pile radiation may become extremely active and may be handled only by special remote control equipment located in so-called "hot" laboratories. Facilities for this type of work have not been included in the design of the building. Most of the work now contemplated will involve materials of low radioactivity: the problem of personnel injury then arises only if particles become embedded in or on the body. It is apparent that major attention must be given to the location of equipment and operations which are particularly

conducive to the formation of dust and vapors, and that the laboratory as a whole must be adequately ventilated; particular attention must often be given to special dust-collecting equipment.

With these requirements in mind, it will be noted from the general plan, Fig. 1, that the laboratory has been designed on a departmentalized basis - an arrangement which has also resulted in some departmentalization of personnel, as would be expected. In general, it was considered desirable to locate all operations involving unusual noise and vibration as distant as possible from quiet operations or operations requiring absence of vibration. Accordingly, melting, casting, and mechanical working equipment has been located in one end of the building along with the dust control equipment, motor generators, high-frequency converters, and other auxiliary equipment required for the operation of the building and its facilities. It develops that these operations are also most conducive to the formation of dust and other health hazards, and their segregation somewhat simplified the problem of personnel protection. Furthermore,

^{*}The facilities to be described were constructed under the administration of W. A. Johnson who was director of the Metallurgy Division from September 6, 1946, to October 1, 1948. During this period Dr. Johnson was on loan from the Westinghouse Electric Corp., but has since returned to his duties with that firm. The present director of the Division is John H. Frye, Jr.



this arrangement simplifies the distribution of many of the services required for the operation of the building and its equipment. For example, the heavy load of electrical power required for the melting and mechanical working equipment is thereby localized.

The rooms in the central part of the building have been designed for various specific purposes. Included are individual laboratories for mechanical testing, creep testing, physical testing, and X-ray diffraction. This section also includes several physical-metallurgy laboratories for special projects, the division shop, and the library. The other end of the building is divided into two sections, one for metallographic and the other for chemical work. The metallography section is completely equipped: the chemistry section is less inclusive, but it has been designed to handle most of the chemical problems of the division other than analytical. Included in this section are facilities which have been specifically designed for corrosion studies on the various metals and alloys involved in the atomic energy program.

Space along the sides has been devoted to offices, conference rooms, storage and building maintenance facilities.

The building proper is of Quonset construction utilizing the entire height (17 to 20 ft.) for the ceiling in the melting and casting and the metal working laboratories. The other rooms and laboratories have 12-ft. ceilings with a plenum above for service lines, dust-collecting and air-conditioning ducts. Asphalt tile floors have been used in all

Fig. 1 — Floor Plan of Laboratory for Metallurgical Division of Oak Ridge National Laboratory. Shaded regions indicate contaminatable areas. Note that some doors are to be used in emergency only. Building is 103 by 220 ft.

sections except the melting and casting and the mechanical working laboratories, which have been provided with a smooth, hardened concrete floor which may be easily cleaned. The wall construction is glazed tile, not only as a protection against fire but for ease of cleaning and decontamination. At three locations this wall extends to the top of the building for a fire barrier; all duets through these walls contain automatic dampers so as to prevent the spread of fire — a particularly important matter in the high-velocity dust-collecting system.

Appropriate heating and ventilating systems have been installed in the individual areas. One system has been designed to provide a flow of air from the offices into the corridors and thence into the end of the building containing the melting, casting, and mechanical working operations so as to prevent dust and vapors from the latter areas reaching the rest of the building. A second

system provides the laboratories in the central portion of the building with conditioned air to maintain a temperature of 70° F. throughout the year. In addition, the metallography and chemistry sections and a portion of the physical testing laboratory are maintained at 45% relative humidity in order to meet the requirements of operation of precision instruments, the preparation of metallographic specimens, and the storage of photographic material.

Control of the dust and vapor hazard is maintained through the use of an exhaust system of

19,000 cu.ft. per min. capacity, and by proper housecleaning. The major sources of dusts and vapors are the melting, casting, and mechanical working operations; to adequately cope with this problem, all equipment in these laboratories is individually hooded. These include hoods around the vacuum furnaces, open melting furnaces, mold shakeout tables, heat treating facilities, and equipment such as the rolling Metallurgical studies of the heavy elements, the trans-uranium metals, and materials for reactors and power piles, require unusual precautions against contamination of personnel, equipment and building structure by radioactive or toxic fumes or particles — even when the level of activity is far too low to confine the materials to a "hot" laboratory. This description of the newly completed metallurgical laboratory at Oak Ridge National Laboratory gives a good idea of how these conditions are met.

mill, extrusion press and swager. All these hoods are connected to a main duct system and the dust removed by a leattery of four cyclone separators and filter hank of extremely high efficiency (Fig. 2). The cleaned air is then discharged through a stack. The design velocity of the air in the ducts of the dust-collecting system is 4000 ft. per min. To maintain this velocity at all times and also to maintain balance in the heating and ventilating system, whether or not the hoods are in operation, suction relief valves have been installed at appropriate locations.

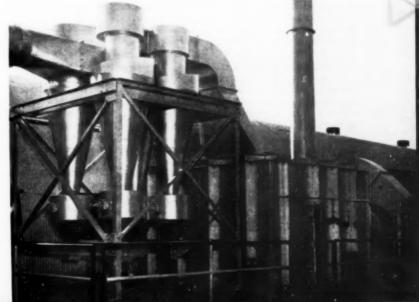


Fig. 2 — Dust-Cleaning System Showing Cyclone Separators, Filter House, Blower and Stack

Protection Against Radioactive Dust

It has not been considered advisable to confine all the work on hazardous materials to the contaminatable area for two reasons - first, many experimental procedures with active material do not produce any dust problem, and second, some procedures producing dust cannot logically be isolated from a sequence of which they are an integral part. To meet the conditions produced by the latter, special or standard fume hoods have been installed at appropriate locations and connected with the high-velocity exhaust system discharging into the dust collector. Particular attention may be called to the special precautions which have been taken in hooding the equipment utilized for the preparation of metallographic specimens prior to wet polishing. Cutting and grinding produce fine dust, and each piece of equipment in the specimen preparation room is practically surrounded by a hood with the exception of an opening large enough for the operator's hand. Most of these hoods have been made of transparent plastic for maximum visibility. These precautions, along with the high air velocity through the opening, seem to be a practical solution to the dust problem.*

Furthermore, it has been advisable to isolate the melting, casting, and metal working laboratories from the rest of the building and to designate them as "contaminatable areas". Personnel regularly working there are assigned protective clothing and shoes (the laboratory attending to laundry and repairs) which are to be worn only in this area. At the day's end, their clothes are placed in a special locker; after showering, each man makes a check for radiation before dressing. Personnel desiring to enter this contaminatable area for short periods of time don shoe covers and smocks at the entrance, redepositing them before returning to any other part of the laboratory.

It is almost impossible to prevent the formation and some spreading of dust or particles of scale around the equipment and on the floor. Complete hooding of the equipment is frequently impractical, and personnel are protected by the use of proper respirators, although adequate protection is usually provided by the exhaust system. In any event, good housekeeping is mandatory, and both equipment and floors are frequently vacuum cleaned and the floors scrubbed.

If it is necessary to carry materials and equipment presenting some health hazard into other sections of the building, they are cleaned and surveyed for radiation before moving; and a check is maintained in these sections for possible contamination. These checks are made by a representative of the Health Physics Division of the Oak Ridge National Laboratory. (As a matter of interest, it is one of the duties of the Health Physics Division to advise on operations and experimental procedures involving radioactive materials. An individual researcher may call on Health Physics at any time for a survey of his equipment or operation.)

Two types of laboratories have been established in the building: those containing relatively standard equipment, such as melting, casting, mechanical working, mechanical testing, metallographic, and X-ray diffraction, and those for projects not requiring such functional equipment. For the latter purpose four physical-metallurgy laboratories of approximately equal size are located along the inner corridor; a larger one is adjacent to the departmental shop. These are not originally provided with any standard experimental equipment whatsoever but each has a workbench, laboratory tables, and the ordinary services (gas, hot and cold water, compressed air, electric power). A universal power panel has been installed in each laboratory through which a wide range of alternating and direct currents and voltages may be obtained. As noted above, these laboratories are also equipped with hoods connected to the high-velocity exhaust system where special apparatus may be placed when hazardous materials are involved.

The various laboratories utilizing more or less standard equipment are designed so as to be used (to a large extent) in studying the various metals and alloys important to the atomic energy program and the development of fabrication methods.

Vacuum Melting

Gas absorption is one of the major problems encountered in the melting and casting of many of these metals. Not only is oxygen pickup important, but nitrogen and hydrogen are considerably more active than with the more conventional metals. Accordingly, a major effort has been made to reduce this contamination to a minimum. At the present time two of the proposed four highvacuum furnaces have been installed in the melting laboratory on a balcony above their respective vacuum sources; this makes for maximum ease of operation and maintenance of both units. The vacuum units consist of a high-capacity oildiffusion pump (capacity 1100 cu.ft. per min. at 10 microns pressure) backed by a mechanical forepump; the resulting unit is able to maintain reasonable vacuum during severe gas evolution by the

^{*}For some ideas on details of construction of laboratory benches, furniture and other facilities, the reader may turn to p. 239,



Fig. 3 - Melting, Casting, Metal Working and Heat Treating Laboratories

metals being melted. Inert gases such as argon and helium may be bled into this system. The power source is a 50-kw., high-frequency motor-generator set.

Several tilting furnaces open to the atmosphere are also connected to this power source. Other requirements are met by smaller high-frequency converters, induction melting furnaces, and conventional resistance furnaces.



The operations of open melting and casting, opening of the vacuum furnaces, cleaning of crucibles, and cleaning and removal of ingots from molds represent the most hazardous conditions encountered. Consequently, these furnaces are very carefully hooded, and the special crucible cleanout is totally enclosed except for a slotted opening wide enough for the operator's arms, and it is provided with a very high-velocity down-draft to prevent any dust from escaping into the room.

Forming and Heat Treating Equipment — Mechanical working and heat treating have been located adjacent to the melting and casting room and occupy the major portion of one end of the building. The equipment is located as shown in Fig. 3; it provides the metallurgy division with excellent facilities for research in fabrication by extrusion, rolling, forging, and swaging. Locations are such as to make available any one of several furnaces

Legend

1-Tool cabinet and stock bins. 2-2-kw. resistance melting furnaces (hood). 3-Casting benches (hood). 4-10-kw. resistance melting furnace (hood). 5-20-kw. spark gap con-6-Small induction melting furnace verter. (hood). 7-Workbench (movable hood). 8-Sink. 9-Mold shakeout hood. 10-Mechanical and diffusion pumps. 11-Motor starter. 12-50-kw., 3000-cycle, 400-v. motor-generator set. 13-Capacitor bank. 14-Switch panel for high-frequency circuit. 15-12-in. vacuum induction melting furnaces (hood). 16-50-lb. open induction melting furnaces (hood). 17-Control panel for high-frequency circuit. 18-Crucible cleanout hood. 19-Workbench (movable hood). 20-Electrical switchgear for 110, 220, 440-v., a.c. circuits. 21-15-kw., 125/250 v., d.c. motor-generator set. 22-Control panel for d.c. circuit. 23-Batteries for 2/24 v., d.c. circuit. 24—Tool cabinets. 25—Gas purifica-tion system. 26—"Exogas" generator. 27— Tool cabinet. 28-Workbench (movable hood). 29-Sink. 30-Electrical distribution panel. 31-Small resistance heat treating furnaces. 32 Rotary swaging machine (hood). 33-1600 ft-lb. electro-pneumatic forging hammer (hood). 34-7.5 & 15-kw. resistance heating furnaces (hood). 35-Furnace temperature control panel. 36-6 x 10-in. rolling mill (hood). 37-42-kw. high-temperature resistance furnace (hood). 38-700-ton extrusion press (hood). 39-Extrusion press controls. 40-Air-hydraulic accumulator. 41-Hydraulic pump. 42-Water storage tank. 43-Air compressor. 44-Prefill tank. 45-Wet abrasive cutoff machine (hood). 46-Special equipment.

Legend

1-Wet abrasive cutoff machine (hood), 2-Wet powder grinder (hood). 3-Wet belt surfacer (hood). 4-Dry belt surfacer (hood), 5-Disk grinder (hood). 6-Protective clothing cabinet. 7-Tool cabinet. 8-Workbench (movable hood). 9-Specimen mount presses. 10-Hand grinders (movable hood). 11-Sink. 12-Chemical etching sink (hood), 13-Electropolishing bench and sink (hood). 14-Two-speed, single-unit polishing machine. 15-Variable-speed, single-unit polish-16-Two-speed, triple-unit polishing ing machine. machines. 17-Metallographic and chemical supplies cabinets. 18-Binocular metallurgical bench microscope. 19 Desiccating cabinet. 20-Stereoscopic wide-field microscope. 21-Photomacrographic camera. 22-Metallographic specimen filing cabinet. 23-Photographic negative filing cabinet. 24-Research metallographs. 25-Desiccating cabinets. 26-Loading and unloading benches. 27-Developing and washing sinks. 28-Sinks. 29-Negative dryers. 30-Refrigerated water cooler and thermostatic mixer. 31-Print dryer. 32-Contact printer. 33 Enlarger, 34 Print washer, 35 Developing sink. 36-Sink. 37-Photographic supplies cabinets.

to each piece of equipment; in this way the operator has a wide range of temperatures and furnace atmospheres available. The extrusion process seems to be one of the most feasible methods of fabricating many of the metals and alloys utilized in nuclear reactor design, since they are less ductile than many of the more common metals, and adequate facilities have been provided with the installation of a 700-ton extrusion press.

Several large furnaces for preheating are also available for any type of general heat treatment. The main installation of furnaces includes a 7.5-kw. furnace, three 15-kw. furnaces, and a 42-kw. "Globar"-type furnace for high-temperature use. Several small muffle furnaces and tube furnaces are placed in this room, to restrict most heat treating operations involving hazardous materials to the contaminatable area.

Since there are very few cases in which the metals under consideration may be heat treated in the open air, it has been necessary to provide various protective atmospheres. Accordingly, each of the furnaces has available to it controlled atmosphere directly from a 500-cu.ft. per hr. "Exogas" generator, located in the corner of the laboratory. Unfortunately, this atmosphere is only partially protective in many cases, so auxiliary piping systems from a central location deliver purified helium, argon, or other gases. The purified argon and helium system also extends into the physical-metallurgy laboratories; it has been designed with a capacity of 75 cu.ft. per hr. of purified gas. Frequently it is necessary to resort to vacuum heat treatments, and equipment for this purpose is also available.

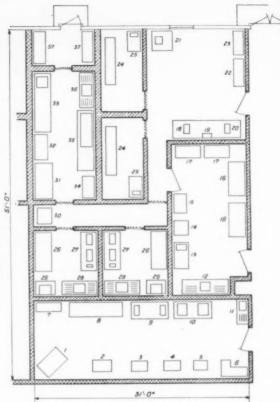


Fig. 4 — Equipment Layout in Metallography Laboratory

Temperatures of the extrusion press container and the various furnaces and other pieces of equipment are controlled through a central instrument panel. Thermocouple and contactor control lines are brought overhead and connected into five-pole sockets properly numbered. Similarly, the recording controllers on the panel are connected to a series of sockets located immediately below those connected to the furnaces. Thus, any furnace may be connected to any of the instruments. In order to have a continuous check on temperature of the load, each furnace has an auxiliary thermocouple outlet through which a second thermocouple with flexible leads may be placed in contact with the load. This load-temperature is relayed to a master busbar on the control panel. Any load-temperature may then be recorded as one of the points of any recording instrument.

Special Sections — The metallography section consists of a group of interconnecting rooms for specimen preparation, polishing and etching, macroscopic examination and photography, microscopic examination, and dark rooms. (See Fig. 4.)

The equipment is "standard" except for the hoods in the specimen preparation room (described previously) and the hoods over the electrolytic polishing and chemical etching sinks.

Two of the major problems anticipated in future nuclear reactors involve materials of high corrosion resistance and of good high-temperature properties. These are, of course, major metallurgical problems. Consequently, the actual testing laboratory in the corrosion section has been designed with a half-height ceiling so that the various solutions could be made up in large quantities and stored on the upper floor. From here they may be gravity-fed to the corrosion units located below. The corrosion laboratory is located near the laboratory for general chemical work, a balance room, an instrument room, and other equipment required.

Facilities in the creep laboratory will be rather conventional except for the provisions for removing, from the vicinity of each instrument, vapors and dusts (as well as heat which might arise from oxidation). Accordingly, creep machines will be placed in two rows extending the full length of the room; above each will be a high-velocity exhaust hood.

A wide research and development program in a new field requires the design and construction of special types of equipment and the development of special research techniques. In the short time this laboratory has been in operation, several problems have already required this type of approach.

The most unusual is a piece of equipment for studying the response of metals to very high thermal gradients, resulting from the rapid cooling of the surface of metals heated internally by heavy electrical currents. It is capable of recording temperature gradients resulting from the dissipation of small amounts of heat up to several hundred kilowatts. Another instance of special methods, although certainly not new, is vacuum arc melting in water cooled metal crucibles, whereby contamination from absorbed gas and crucible materials may be avoided.

Interchange and Advancement of Personnel

The metallurgy division is fortunate in that, being a part of the Oak Ridge National Laboratory, it may call upon the services of the scientific and technical personnel of the other divisions. Thus, at the present time chemical and spectrographic analysis and a portion of the X-ray diffraction work is being carried out by the chemistry division.

A cooperative program on solid-state physics has been under way for some time with the physics division, a program directed toward the solution of several fundamental problems required to substantiate or to develop further the theories of the solid state. A considerable portion of the work on the response of metals and alloys to the conditions met in nuclear reactors, however, will be directed along lines of interest to both the metallurgist and the physicist. Research in this field is complicated by the radiation hazard and necessitates new procedures, techniques, and equipment in laboratory experimentation. Practically all of the work must be done behind barriers which adequately protect the personnel, and all operations must be carried out by remote control. These include the more familiar metallurgical operations such as hardness testing, tensile testing, and even the preparation of metals for both macroscopic and microscopic examinations. The need for care and ingenuity of the researcher in these investigations may well be appreciated.

Another interesting field of cooperative research between the physics and metallurgy divisions is that of neutron diffraction. There are indications that it will extend the areas now occupied by electron and X-ray diffraction methods, particularly to locate the lighter elements in metal structures, since the neutron beam is selectively diffracted by the lighter elements. One problem of particular interest in metallurgy is the exact location of the carbon atoms in the iron lattice.

The metallurgy division has cooperated with universities offering graduate studies in metallurgical fields. This plan functions through the Oak Ridge Institute for Nuclear Studies. Students who have completed their classroom work at their university may spend sufficient time at the metallurgy division's laboratory for completion of a research project. These students are being selected by agreement between the laboratory and the university. It seems feasible for students on Master of Science programs to complete their research problem in one or possibly two summer periods. Although no doctorate research projects have been sponsored by the metallurgy division, a program has been organized through the Oak Ridge Institute, wherein the candidate is required to complete all course work and preliminary examinations at his university; he is then assigned a mutually agreeable problem. At least one full year, and perhaps more, is devoted to research on this problem; its satisfactory completion is verified to his graduate school by examiners from the laboratory and the university.

The full-time personnel of the division are also given the opportunity and are urged to take graduate work on a part-time basis. A program has been set up whereby they may obtain Master of Science and Doctor of Philosophy degrees.

Furnaces for

Gas Carburizing;

Design & Operation

ADVANCEMENTS in the design of controlled atmosphere furnaces have kept pace with the increasing knowledge of gas chemistry. This is a tribute to both the furnace user and the furnace designer. One of the most important functions performed by the furnace manufacturer is the circulation of ideas from plant to plant. On the receiving end, the steel treat supervisor has never been adverse to changing the design of existing equipment to meet the current requirements of the product. Such changes are often made with the assistance of the furnace company and later incorporated into new furnaces to the advantage of the whole fabricating industry. Such has been the situation at Spicer Mfg. Division of Dana Corp., where six gas carburizing furnaces are used for case hardening the shafts and gears which go into the automotive rear axle units, heavy-duty transmissions and torque converters made by Spicer.

It is not the purpose of the writers to discuss here the elementary design features common to most atmosphere furnaces. Let it suffice to say that our furnaces are tight enough so an internal pressure of 0.15 to 0.30 in, of water can be maintained with a reasonable input of prepared gas. Also the hairpin-type radiant tubes are spaced sufficiently close for uniform heating, and are divided into zones whose temperatures are automatically controlled to give the desired cycles on

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the work passing through.

Gas carburizing originally started out as a heating in an atmosphere of straight natural or manufactured gas or in a mixture of either of these gases with air. As might be expected, such operation was unsatisfactory due to the prohibitive amount of carbon deposited as soot or coke on the steel surfaces. Since carburizing is a result of absorption of nascent or atomic carbon from the atmosphere at the steel's surface, such deposits actually impeded the process. A much more serious effect

was the nonuniform case depths produced and the unequal cooling rates obtained during quenching; both these factors increase the distortion during hardening. Plug or die quenching was no solution, since the hard carbon deposits prevented insertion of the plug or interfered with normal die contact.

It early became apparent that a less carbonaccous atmosphere was required, and a variety of gas cracking units, or "generators", were developed. One of the simplest types, which is still used extensively, is the catalytic, endothermic generator in which a mixture of hydrocarbon gas and air is cracked at approximately 1850° F. in a retort containing a refractory impregnated with nickel. The nickel catalyst controls the reaction so the hydrocarbon is virtually completely changed to hydrogen and carbon monoxide with only traces of carbon dioxide and water vapor.

For natural gas (which may be assumed to be approximately 100% methane) or a hydrocarbon equivalent to natural gas the reaction is

 $CH_4 + 0.5O_2 + 1.89N_2 = CO + 2H_2 + 1.89N_2$

in which 4.89 cu.ft. of generator gas are made for each cubic foot of methane cracked. Since the mixture of 2.39 cu.ft. of air with one cubic foot of methane will not support combustion, external heat is furnished to the retort, either by gas burners or electrical resistors. (The gas required by the burners, in a normally insulated unit, is

approximately 90% of the gas cracked.) The heat from the burners furnishes the heat absorbed by the endothermic reaction above, as well as compensates for radiation losses, and the heat carried away in the exit.

It is seen, then, that the use of a generator gas in carburizing has the advantage of economy as well as cleanliness, since about 2.6 volumes of generator gas are produced for every volume of methane used for cracking and heating

$$\left(\frac{4.89}{1+0.90} = 2.6\right)$$

The analysis of the gas produced by the cracking of methane is as follows:

$$\begin{array}{ll} \text{CO} = 1 & \div 4.89 = 20.4\% \\ \text{H}_2 = 2 & \div 4.89 = 40.8\% \\ \text{N}_2 = 1.89 \div 4.89 = 38.8\% \end{array}$$

This gas is essentially neutral to steel at normal carburizing temperatures and is furnished to the furnace in relatively large volumes

to build up an internal pressure in the carburizing chamber and prevent the infiltration of air around door openings or through any cracks that may exist in the steel casing. To this neutral, protective atmosphere must then be added an active carburizing gas (such as natural gas) so as to constitute from 5 to 15% of the total volume—the actual percentage depending upon the temperature of operation, frequency of door openings, surface area of the work to be carburized, degree of circulation of gases inside the furnace chamber, and the carbon concentration desired at the steel surface.

Three of the furnaces used at Spicer in the Toledo plant are divided into two zones of automatic temperature control, while the remaining three have four zones of control. Other descriptive features are listed below.

	TWO-ZONE FURNACES	FOUR-ZONE FURNACES
Furnace type	Continuous pusher	Continuous pusher
Method of heating	Radiant tubes	Radiant tubes
Rows of trays	2	3
Trays per row	14	27
Tray size	15 x 19 in.	16 x 21 in.
Control of furnace cycle	Manual	Automatic
Gas circulation	Fan impeller	

The two-zone furnaces are used primarily for carburizing axle parts such as ring gears, pinions, side gears and pinion mates. The tray and loading for ring gears and pinions are shown in Fig. 1

An interesting variant from conventional practice consists of carburizing at 1725, intermediate cooling to 1150, reheating to 1550° F. (all in one trip through a continuous furnace), oil quenching, washing and then drawing at 340°. This increases production rate of heavy parts for automotive transmissions, and produces, in 8620 or 4320 gear teeth, a superior microstructure for clash gears, consisting of fine-grained, relatively low-carbon martensite, with some excess carbide in the surface zone. Such carbides greatly increase the wear resistance and do not harm the impact properties if well distributed — that is, if not accumulated in a grain-boundary network.

and 2, respectively. The alloy spacers between the ring gears are designed so that each gear supports only its own weight while the weight of ones above it is transferred through the spacers to the tray itself. (See Fig. 1.) Such loading minimizes warpage of the gear face.

An internally threaded copper cap is used to suspend the pinion from the tray fixture (Fig. 2). The cap also serves to shut off the circulation of carburizing gases as well as to decrease the quenching rate of the threaded section. Such measures are necessary to prevent cracking when the pinion nut is drawn up during assembly.

Ring Gears Quenched Individually

Due to the heavy tray loading for ring gears and pinions, a recirculating fan has been installed near the roof of each of these carburizing furnaces to accelerate the heating rate and promote uniformity of case depth. For the same loading density, an atmosphere richer in hydrocarbon gas should be used if the furnace does not have a means for recirculating the gases. A lean atmosphere becomes

readily depleted of available carbon in stagnated areas so that the steel in these areas is low in both carbon concentration and case depth.

Typical operational data for the two-zone

furnaces are shown below. Relatively high percentages of hydrocarbon gas are used and no effort is made to limit the surface carbon concentration of the carburized case.

Typical Operational Data for Two-Zone Furnace Temperature: Zone 1, 1700° F.; Zone 2, 1650° F.

Maximum loading, lb. per hr.: 660 net, 1240 gross Total time in furnace: 7 hr.

Atmosphere (cu.ft. per hr.): 600 generator gas plus 80 natural gas

Pressure in furnace chamber: 0.20 in. H.O

GAS ANALYSIS	CO.,	co	CH_A	Н.,	N.	POINT
Influent	< 0.1	18.5	13.3	33.5	34.7	+ 2° F.
Effluent	< 0.1	17.8	5.0	41.9	35.3	+18° F.

At the end of the carburizing cycle the loaded trays are pulled manually from the furnace chamber into the discharge vestibule and subsequently removed for quenching. The fixture holding the pinions is lifted from the tray by an electric hoist

and lowered into a recirculated oil bath maintained at 120 to 140° F. The recirculating oil is directed upward and, due to the shape of the pinion head, the pinions must be quenched head down to quench the gear teeth uniformly.

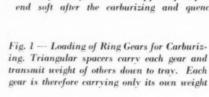
The furnace used for carburizing ring gears has been redesigned to allow the gears to be removed individually and quenched in a press. An alloy muffle or corridor, 18 in. wide and 3½ in. high, has been installed in an opening through the end-wall directly in line with the first row of trays and approximately 2 ft. above the skid rails. The outer end of this small muffle has a sliding door which opens

downward; the inner end of the muffle is open and extends approximately 9 in. inside the furnace back-wall. The hearth plate at the end of the first row of trays is sectioned and connected by alloy shafting to a hydraulic cylinder below the furnace floor so as to form an elevator, as indicated at the right-hand end of Fig. 3.

When the trays are advanced one position by the front pusher, the end tray is pushed onto the elevator. The operator then raises the elevator so the top ring gear is level with the muffle, after which this gear is removed and quenched. A ribbon-type burner is attached to the top of the sliding door and, as the door is lowered, a solenoid valve in the gas line is energized and a flame curtain forms across the door opening. At the same time another solenoid valve in a gas line extending through the furnace wall just below the door opening allows a small amount of natural gas to enter the furnace, thus counteracting any air or



Fig. 2 — A Copper Cap With Internal Threads Is First Screwed Over the Spline End of the Pinion. A pin, inserted through the hole in the cap, or a stirrup, bearing against its shoulder, suspends the pinion vertically in the fixture. The copper cap keeps the threaded end soft after the carburizing and quenching cycle





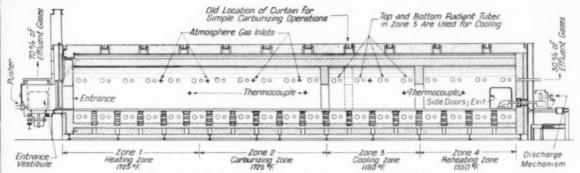


Fig. 3 — Longitudinal Section of Four-Zone Furnace Adapted From Simple Through-Type Carburizing Furnace. (Courtesy Surface Combustion Corp.)

products of combustion from the flame curtain that might enter the furnace while the door is down. The door is open just long enough to extract one gear for each of the four presses

and then closed again until the next quench cycle. After all the gears on that tray have been quenched, the elevator is lowered and the empty tray removed through the regular side discharge vestibule. At the proper time a tray from the second row can then be pushed transversely onto the elevator by a cylinder operating through the furnace side-wall, and the quenching procedure is repeated.

Handling Carbon Steel for Least Distortion

A third two-zone furnace is used for miscellaneous work such as hardening or carburizing followed by slow cooling. Practically all the plain carbon steels used for spacers or bushings are carburized and cooled in this furnace. They are then reheated to approximately 1475° F. in a small belt-type electric furnace and hardened in water. Such a procedure causes considerably less distortion than the double quench treatment, and produces a hard, fine-grained case with a soft, moderately tough, unrefined core.

For this work on plain carbon steels a relatively lean atmosphere, consisting of 600 cu.ft. per hr. of generator gas and 50 cu.ft. per hr. of natural gas, is used during the carburize-cool cycle to prevent excessive sooting of the work. All the atmosphere gas is put into the furnace through the inlet ports in the hot zone and no recirculating fan is used.

Maximum loading (lb. per hr.): 920 net, 1450 gross Total time in furnace: 10 hr. 48 min.

Atmosphere (cu.ft. per hr.): 1000 generator gas plus 125 natural gas

Pressure in furnace chamber: 0.20 in, H₂O

Analysis: CO., CO CH4 H. N2 DEW POINT Influent < 0.118.2 13.4 32.0 36.3 + 2° F. Effluent 0.1 18.1 5.8 38.7 37.3 +22° F

The second zone of the furnace is converted into a cooling zone simply by closing the zone's gas valve and adjusting the automatic temperature control instrument so that the air control

valve is open and cold air is drawn through the radiant tubes. The work emerges bright at a temperature of 850 to 950° F, and is only slightly discolored by oxidation during the subsequent cooling in still air.

Two-Heat (Reheat) Cycles for Heavy Work

The large four-zone furnaces were originally used for carburizing and direct quenching. Zone temperatures were controlled at 1650, 1700, 1600, and 1550° F., respectively; most of the parts were reheated in atmosphere hardening furnaces. During the war, when every effort was being made to obtain greater production from existing equipment, the idea was conceived of carburizing, cooling to below the critical, and reheating for quenching, all while going through the furnace once. To accomplish this, the original third zone was lengthened to include the last two tubes from the second zone. Jack arches, just high enough to allow passage of the work, were installed in the roof, and the refractory piers directly below the jack arches were bricked up solid to separate zone from zone as much as possible. Air from an auxiliary blower, 635 cu.ft. per min. capacity, was piped through control valves to the discharge end of the eight hairpin tubes in this zone, thus being forced through in a reverse direction from that normally traversed by the combustion gases when the tube is used for heating.

The operating temperature controls for the first and second zones were increased to a 1725° F. setting to compensate for the carburizing time lost in the cooling zone. A longitudinal section of the furnace as it now exists is shown in Fig. 3 (top p. 197) and typical operational data are tabulated in the caption.

The atmosphere gas is mixed with the natural

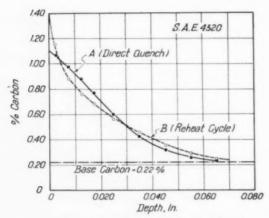


Fig. 4 — Carbon Gradients From 1-In. Test Bar Carburized Alongside Work in Production. Curve A represents conventional cycle — carburize at 1700 to 1650° F. and oil quench. Curve B represents present cycle in four-zone continuous furnace — carburize at 1725° F., cool to 1150° F., reheat to 1550° F., and then oil quench

heat treatment, and in order to obtain quiet running gears with proper tooth contact of the mating parts, it is essential that the gear faces do not warp or the teeth taper. The parts are checked 100% by the heat treat inspection department and any gear showing warp or taper in excess of 0.003 in. is rejected.

One of the furnaces is equipped with an automatic "lowerator" which quenches tray, work, and fixtures, if any, immediately after the loaded tray is discharged from the furnace. When the parts are properly racked, distortion is held to a minimum by this equipment and the results are consistent from day to day. Most of the gears that were formerly quenched in presses are now being hardened satisfactorily with a modified martempering treatment. Gears having internal splines are usually plug quenched in oil at 130° F. or given a modified martempering treatment. Plans are currently being made for quenching these splined gears in an open tank without a plug, after which the splines will be ground or honed to finish dimensions.

Transmission parts carburized in the four-zone furnaces are transferred to an adjacent continuous belt-type wash and recirculating draw unit and drawn at 340° F. for 40 min. (minimum time at temperature). The parts are file-hard after quenching and have an indentation hardness of C-62 to 65. Hardness after drawing is C-59 to 62 and the gears have a slight file touch.

Axle gears carburized in the two-zone furnaces are made from fine-grained 8620 steel.

gas and introduced through inlet ports in the first two zones. The two effluent vents are adjusted to exhaust approximately 70% of the gas through a vent pipe in the charge vestibule and the remaining 30% through a vent pipe at the discharge end of the furnace. The temperature control and the mechanical operation of the furnace is entirely automatic except that the loaded tray is removed from the side discharge vestibules by the operator after a horn indicates the cycle end.

Practically all the parts run through these four-zone furnaces are gears and shafts for heavy-duty transmission and torque converters, made from fine-grained 8620 or 4320 steel. The work is quenched by various methods, depending on the shape of the part and the dimensional tolerances allowed. Very few of the gear teeth are ground after

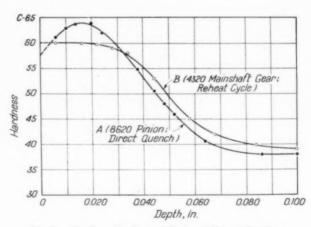


Fig. 5 — Hardness Gradients of Pinion of Fig. 2 After Conventional Cycle (Oil Quenched), and a Mainshaft Gear After the Reheat Cycle. See caption of Fig. 4 for cycle specifications. Mainshaft gear was also drawn at 340° F.

Approximately 10 to 20% of austenite is retained in the outer portions of the case after quenching, and no subsequent draw is given. The gears are hard to a mill-file; any evidence of soft skin is cause for rejection, since such surfaces frequently score in service.

Carbon and Hardness Penetration

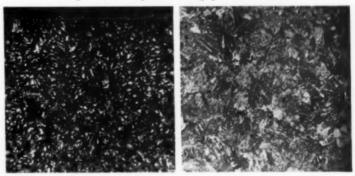
Typical carbon and hardness gradients for the carburizing cycles described above are shown in Fig. 4 and 5. The carbon gradients were

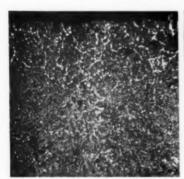
obtained from chemical analyses of turnings taken from 4320 test bars, 1 indiameter, run with loaded production trays. The hardness gradients were plotted from 5-kg. Vickers impressions taken across the case at the pitch line of the gear tooth cross section.

Figure 6 shows photomicrographs of the case and core of a ring gear tooth, while Fig. 7 represents a tooth from a mainshaft gear. Distinct differences will be noted between the microstructures of the case. gear tooth. These superficial carbides have no deleterious effect on impact properties, providing they do not form a continuous network at the grain boundaries.

Experience indicates that the high-carbon martensite formed in the direct-quenched axle gears will withstand "tempering" during service better than the low-carbon martensite found in reheated gears. Since the axle gears are in constant mesh, high impact properties are not required. Indentation hardness falls off near the surface, as indicated by Fig. 5, due to the austenite

Fig. 6 — Case and Core of Tooth of A.I.S.I. 8620 Ring Gear, Direct Quenched, Magnified 400 Diameters





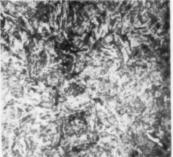


Fig. 7 — Case and Core of Tooth of S.A.E. 4320 Mainshaft Gear, Treated in Two-Heat Cycle and Drawn (Curve B of Fig. 5)

The clash teeth of transmission gears must withstand impact loading, and a carburized case consisting of fine, relatively low-carbon martensite with fine, well-distributed carbides is desired. The excess carbides near the surface, indicated by both the carbon gradient and the photomicrograph, greatly increase the wear resistance of the

retained in this portion of the case.

Solution of carbon is complete in the core of both direct-quenched and reheated gears, as evidenced by the photomicrographs, as well as by their core hardness, C-38 to C-39.

Some constant-mesh transmission gears are carburized on the direct-quench cycle for which the four-zone furnaces were originally designed. However, the preponderance of the work, including all clash gears, is treated

according to the reheat cycle described above.

Our carburizing procedures may be somewhat at variance with methods followed in other plants. However, they have been adopted after comprehensive laboratory and field tests, and are justified by the commendable results obtained in service — which is, of course, the real criterion.

President, American Society for Metals



Harold Knowlton Work

A Biographical Appreciation

WHEN the committee for nominating national officers of the American Society for Metals met in 1947, it had before it this document supporting the candidacy of HAROLD WORK, signed by a group of his work-a-day associates:

"Dr. WORK was elected to his present office in the Society in recognition of his prominent position in the metallurgical field. He has also held national offices in other technical societies. He has received awards for distinguished achievements. He has presented numerous technical papers and has lectured nationally on both ferrous and nonferrous subjects. His organization and leadership of the research activities of his company have resulted in outstanding steel-producing developments which have been accepted by the entire industry.

"An attached biographical and professional history will serve the purposes of record. It is not possible, in the same formal way, to do justice to Dr. Work's truly attractive personality. He is cooperative, sympathetic to the ideas of others, and completely unselfish of his time. His honesty and integrity are wholly beyond question. He is eminently practical, congenial, and a good mixer. He possesses all the qualities of a real leader. Although we have listed his professional achievements as references for the office of Vice-President of the American Society for Metals, we endorse him equally strongly because he is truly a gentleman."

That having been said, the present biographer feels that his pleasant task is completed. For the record a lot more might be added, probably, to the effect that Harold Knowlton Work, currently President of the American Society for Metals, was born on May 22, 1901, in Hartford, Conn., and in due time entered Columbia College in the City of New York, from which he graduated in 1923 as a Bachelor of Arts. Two years later Columbia's Engineering School dubbed him a Chemical Engineer, he having fulfilled the academic requirements therefor, and having acquired the Illig medal for scholarship, five honorary keys, and also having rowed on the 150-lb. crew.

This was the kind of man Aluminum Co, of America could use, so Work entered Mellon Institute in Pittsburgh as Alcoa's industrial fellow to study the surface treatment of aluminum. During the next four years, 1925 to 1929, he discovered the first practicable method of electroplating the aluminum alloys (incidentally receiving his Ph.D. from the University of Pittsburgh). Later on, with Alcoa, he did outstanding and important work on anodic treatments and the "alumilite" process, becoming expert in the broad field of surface finishes for aluminum and its alloys.

1925, 1936, and 1949 are important milestones in Harold Work's business career. Consider 1936, when Jones & Laughlin Steel Corp.'s directors decided that some real money should be spent in the study of variables in the steelmaking process, especially their influence on the quality of the product - common, ordinary carbon steel. Here was a central idea, excellent in itself, but valueless unless translated into a specific program carried through by a competent staff. First was the job of finding a director of research, and HAROLD WORK was the choice, not because he was a steel expert (possibly a steel "expert" would have failed to see the things that could be done because he knew so many things that couldn't be done) but because he had solved some tough chemical and physico-chemical problems concerning another metal. He had the inquisitive approach, a competent scientific background, abounding physical energy, demonstrated leadership.

The history of his next 13 years is the history of J. & L.'s research and development division. First a central laboratory had to be built and manned. Next a 4-ton openhearth furnace had to be designed, built and instrumented. No less difficult, the melters had to learn how to operate it so as to parallel the action of a big openhearth, despite the fast changes in the shallow bath. Results certainly exceeded expectations; a few specific achievements include the discovery of a superior steel for deep drawing, an improved steel for drill pipe, and several alloy steels for special

use by Army Ordnance.

The research team also had as a prime objective the study of the bessemer process - then all but neglected by metallurgical science, and waning in importance in the American industry. As a result of intensive plant work, bessemer control by educated eye has been supplanted in all J. & L. plants (and in many others) by photocells which record instantaneous and quantitative changes in the flame. Nitrogen in steel - a difficult subject also came in for scrutiny. It was found that nitrogen was swept out of a high-carbon openhearth melt if the carbon was worked down very rapidly: a nonaging sheet steel resulted. A duplex process for controlled nitrogen steels was developed. The side-blown converter was studied; it can make a low-nitrogen steel, and runs so hot it absorbs 40% of cold metal in the charge - even more, if blown with oxygen-enriched air.

Nor were the activities restricted to steel-

making. Close attention was given to the raw materials, working back through the blast furnace process, to the sintering of fines, to proper preparation of ore from Michigan and New York State, and finally to a new laboratory in Negaunee to study low-grade magnetites from the Iron Ranges.

This is a record of diverse achievement indeed. One of Dr. Work's principal associates characterized the plan of operations thus: "We usually started with a suggested idea - sometimes it was pretty vague - but we would then work out a plan of study. After we had discovered the facts, we had to decide whether changes should be made in steelmaking operations. Then came the real job of getting the information into the plants and into the minds and reflexes of the operators. Dr. Work always liked the hard jobs; to his staff members he was uniformly genial, sympathetic and encouraging, ruling principally by example. His technical conversation was always full of enthusiasm for the accomplishments of his associates."

The latest milestone in the business career of HAROLD K. WORK, president , is his appointment at the beginning of this year as director of the research division, College of Engineering, New York University. Organized like the better known prototype at Ann Arbor, New York University has some 115 full-time researchers and 40 faculty members working part time. [Considering the budgets of such organizations in a few colleges and universities, this matter of "sponsored research" has indeed grown to big business.] Much of the current program is beyond the field commonly occupied by an engineering college and has to do with the relation of men and machines - truly a difficult field of endeavor, but just the thing for the clear-thinking inventor of aluminum electroplating process and photocell bessemer control.

The only thing that bothers this biographer himself a graduate commuter - is how HAROLD WORK is going to harmonize his principal hobby to his new environment. A gardener of betterthan-average ability, his wartime farm was a matter of neighbors' envy, going far beyond the ordinary vegetables into fruit trees (specially grafted a-la-Work), and later a riot of flamboyant gladioli. He surrounded the J. & L. laboratory at Hazelwood, across the street from a smoky steel plant, with velvety lawn-less I suspect to demonstrate to complaining residents that green things can grow in a mill town, than to express his love for the outdoors. At any rate, the grounds-keeper was once accosted by the passing priest. "That's a fine lawn the Lord and you have grown, my son." "Yes, father," he replied, "but you should have seen the place when the Lord was going it alone!"

MARTIN SEYT

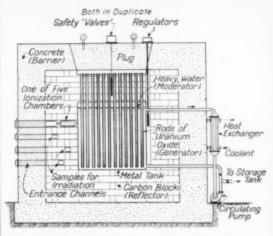


Diagram of French 10-Kw. Reactor, Using Bars of Sintered Uranium Oxide Immersed in Heavy Water for Moderator. Relative dimensions are purposely distorted

A SPECIAL ISSUE of the quarterly journal Atomes (Feb., 1949) commemorates the completion of the first stage of France's atomic energy program, with special articles by Frederick Joliot-Curie, chairman of the Atomic Energy Commission; Eugene Le Meur, chief mechanical engineer; Maurice Surdin, chief electrical engineer; Bertrand Goldschmidt, chief metallurgist; and an interview with L. Kowarski, technical director for the Commission.

Most of the French scholars who were studying nuclear fission went to England in June 1940, taking with them their supply of heavy water, and later participated in the Anglo-Canadian project, the forerunner of the American activities. The supply of commercial black uranium oxide (U₃O₈),

96 to 97% pure, was hidden at Maroc.

The refugee scholars were reassembled early in 1946, following the passage of the national law establishing the French Atomic Energy Commission. "We started out almost from zero on the first stage of the development, the construction of a 10-kw. pile using uranium oxide and heavy water [nicknamed Zoé]. Active work on this required 15 months' labor of some 400 people; the pile began operating on Dec. 15, 1948. The second stage of the French program, planned for completion in 1953, is the construction of one or two piles of medium power. cyclotrons and other accelerators, and a large center for nuclear studies at Saclay. The third stage to follow will be the design and construction of a power-producing pile. Concurrent with the work of 1947 and 1948 was the training of technicians, and the search for uranium deposits in French territory. The small pile now operating will make radioactive isotopes for biological uses and for scientific and industrial research, provide means to study the materials of construction required for the larger reactors, and train technicians.' Curie

The French Nuclear Reactor

On being questioned about reasons for adopting the general design shown in the accompanying sketch, M. Kowarski said: "A chain reaction can be maintained with less uranium if heavy water* is used as a moderator rather than purified carbon; furthermore, uranium oxide (more easily prepared than metal) can be used for the energy source. Heavy water also simplifies the cooling problem over the task of piping a coolant into and out of the reactor. The necessary piping would be bulky (making the pile larger) and introduce serious and as yet unsolved problems of corrosion and neutron absorption. Even in the construction of this lowtemperature pile (which must operate at less than the boiling point of the heavy water) all our troubles were in the technical field rather than in the scientific. So far, we have been independent of foreign sources for materials and equipment: we have purified the necessary carbon; in fact, we hope to be able to export radio-isotopes and certain specialized electrical equipment in the near future.

"From the mechanical viewpoint, the pile is simply a source of heat." [LeMeur] "The temperature achieved by a chain reaction is unlimited; in our pile the heat must be taken out as fast as it is produced, to prevent vaporization of heavy water. All details must be arranged with the idea that access within the pile is impossible; all parts that must be periodically replaced, such as the uranium bars, must be handled by remote control. Joints and openings must be as tight as possible and have barriers to prevent leakage of harmful radiation. Materials must be rigorously clean and kept so indefinitely; traces of oil or finger marks, atmospheric humidity itself, constitute impurities.

"The necessary purified carbon is not a material of construction; bolts or mortar cannot be used. Each block is machined to very close tolerances. Certain carbide tools cannot be used, for their infinitesimal fragments will form intolerable impurities; rapid machining, however, is required to avoid splintering at the edges. The carbon dust is an abrasive rather than a lubricant, and must be excluded from machine bearings and the machinists' lungs. Obviously, erectors cannot walk on the beds already laid. The tanks and piping must be free from every trace of water from atmospheric humidity. To insure this, we have special desiccation equipment. Pumps cannot be oiled. Every precaution is taken to avoid loss of precious heavy water."

Control is discussed by M. Surdin. "The safety bars, which contain neutron-absorbing elements like boron or cadmium, are normally set in one of two positions, either stop (when immersed in the heavy water) or go (when completely out, as shown in the sketch). Between tank and carbon wall are similar regulator plates, adjustable in elevation to 0.5 mm. through servomechanisms. A steady state of the chain reaction is achieved by the proper relationship between level of heavy water surrounding the uranium and level of the regulator plates.

"Activity of the pile is measured by five ionization chambers, whose electrical response is proportional to the number of neutrons reaching them in unit time. Two are interlocked with the safety valves; two measure and record the power level; the last and most sensitive one measures the variations in power level from the set point [and is interlocked with the regulating plates].

"Any failure in the electrical circuits serving this equipment would release the safety bars. Finally, to protect personnel, equipments throughout the building detect and register the level of gamma and other radiations. Numerous other safety devices are installed; for example, the main pump operates for only 30 sec., and must then be restarted by the chief operator."

M. Goldschmidt, describing the uranium oxide rods, notes that the brown oxide UO₂ is much more easily refined than the metal. Likewise it was successfully used in the first American pile that supported a chain reaction. (As described in the "Smyth Report", this contained 12,400 lb. of uranium as metal lumps and oxide lumps distributed through a mass of pure carbon acting as moderator, and operated up to a power level of 200 watts.)

"Purification of commercial U_3O_8 is based on the fact that uranyl nitrate is one of the few nitrates soluble in ethyl ether, and UO_2 is one of the few peroxides insoluble in acid solutions. Successive steps involve taking a batch of black oxide U_3O_8 into solution in nitric acid, cyclic extraction in ether and re-extraction by water, transforming nitrate into UO_4 by precipitation with H_2O_2 , converting UO_4 to UO_2 by heating at 300° C., and finally to the brown oxide UO_2 by hydrogen reduction at 650° C. This temperature is quite critical; below 650° the brown oxide is pyrophoric and reoxidizes in air; above that temperature it starts to frit and the granules are difficult to form into coherent bars.†

"A plant for producing 100 kg. [220 lb.] of the element per day was built between summer of 1946 and the end of 1947; capacity production was reached within a few months.‡ Present personnel is about 100; their work consists in perfecting the process and getting ready to produce metal for the second stage of the French program. The product is extraordinarily free from the dangerous impurities (boron, cadmium, lithium, the rare earths). Equipment is entirely of stainless steel; the plant is air conditioned with especial attention to removing dust; in certain stages the attendants work under conditions of surgical asepsis. No uranium losses in process can be tolerated. Likewise, the ether extraction plant contains all known safety devices against the explosion hazard."

*Heavy water is H.O wherein the hydrogen is the heavy isotope (weight 2) rather than the lighter isotope (weight 1). All natural water contains 0.02% of it. It is ordinarily concentrated by electrolysis, using the principle that when water is split into hydrogen and oxygen the light isotope is the one evolved.

†Evidently the UO₂ must be cooled, compressed into bars, and the bars sintered under protective atmospheres, Assuming 9 months' capacity operation to equip Zoé, the 10-kw. pile should contain about 30 tons of uranium metal as oxide.

By Francis C. Frary

Director Aluminum Research Laboratories New Kensington, Pa.

The Light

Metal Picture

FROM a structural and engineering standpoint, the "light metals" are aluminum and magnesium. Actually, sodium, potassium, lithium, calcium, barium, strontium and beryllium are also "light" metals as compared with iron, copper, lead or zinc, but their physical and chemical properties make them unsuited for engineering purposes except as constituents alloyed in very small amounts with the more common metals. They will, therefore, not be considered in this discussion.

One of the things of basic importance in this light metal picture is the comparative youth of the metals involved. Commercial production of aluminum by the present process began 60 years ago; while there was some production by chemical methods before that time, the amount was so small and the cost so high that the price was at least \$5.00 a ab., so the uses were of the jewelry store variety. Magnesium is even younger, commercially, than aluminum. On the other hand, the other metals suitable for engineering purposes have been produced and used for centuries some of them for thousands of years - so that their technology, properties and uses were well established and their markets well developed when the light metals appeared. Therefore, these new metals have had to go out and build (or capture) markets wherever they could, in competition with every type of material from paper to stainless steel. This involved not only the development of a technology of producing the metals and their alloys in every commercial form, and their adaptation to the demands of customers, but also the selection and development of the best alloys and products for a tremendous variety of uses, the development of fabrication technique and detailed information on the properties and behavior of these products under a variety of conditions, and the education of the metal fabricating and consuming industries in the methods and advantages of using these products.

From the production standpoint, the light metals differ fundamentally from the heavy metals in having a very much greater chemical affinity for oxygen and other nonmetallic elements. While most of the heavy metals can be easily

reduced from their oxides by carbon, discarding in the slag most of the impurities present in the ore, the commercial production of aluminum or magnesium involves a preliminary quite complete chemical separation of a compound from most of the impurities present in the ore. In the case of aluminum, substantially chemically pure oxide containing less than 0.02% each of silica and iron oxide, and only a few thousandths of a per cent of titanium oxide - must be produced as the first step in the extraction of the metal. In the case of magnesium, high-purity magnesium chloride must be produced from brines or sea water or by chemical reaction upon dolomites or magnesite. Heavy metal or siliceous impurities are reduced more easily than the light metals, and therefore contaminate the product. (The wartime process of producing magnesium from calcined dolomite and metallic silicon, by thermal distillation in a high vacuum, is an exception to these statements, but it is not at present commercially competitive with the electrolytic chloride process.)

Since direct smelting with carbon is impossible, the light metal industry finds itself requiring for this purpose large quantities of electric power, which is an inherently expensive source of energy. This power, to the amount of 8 to 10 kw-hr. per lb. of metal, must be used directly in the electrolytic process (or indirectly in the production of metallic silicon or ferrosilicon for the thermal magnesium process). It is a fundamental and large item in the cost of production, and a limiting factor in the tonnage which can be produced under present conditions.

The gradual development of the light metal industry and its acceleration by the late World War are given in Fig. 1, which shows the production of primary and secondary aluminum since 1910 and the primary production of magnesium. In 1938, when the aluminum industry celebrated its 50th anniversary, production of primary metal had reached a peak of almost 145,000 short tons per annum, and there were about 2000 known uses for the metal. productive capacity rated at 181,000 tons per annum and a metal stock on hand equal to approximately two years' sales, the industry in the United States faced the rapidly growing demand with confidence.

Then came the war, with requirements for increased production of aluminum and magnesium far in excess of those faced, percentage-wise, by any other metal. As the war clouds began to gather, the Aluminum Co. of America sensed the coming needs of the aircraft industry, and started a \$300,000,000 expansion program in new

capacity for the production of bauxite, alumina, carbon electrodes and aluminum, and the fabrication of strong alloy products required for aircraft. Alcoa's producing and fabricating capacity, thus augmented, furnished the material for the American-built planes that helped turn the tide in the Battle of Britain. Further large additions to the producing and fabricating capacity were then built (largely with government money) and began to

1000 Annual Capacity in 1943: 1,162,000 Tons Primary Ingot 800 Total Economical Capacity Jan. 1, 1949 Thousands of Tons 800 Primary Aluminum Production 400 Secondary Aluminum Magnesium 200 1925 /935 1920 1930 1945 /950 Year

Fig. 1 — Aluminum and Magnesium Production of Ingots in the United States Since 1910

An up-to-date account of the distribution of aluminum capacity in the United States and of recent trends in world production. The recent anomalous situation is discussed, where a shortage of metal existed in an industry whose producing capacity was vastly increased over prewar's, and whose principal wartime customer was no longer buying. Indications are that other nonferrous metals will feel competition sharpest from the light metals, whereas iron or steel will be replaced only for uses where the engineering properties of the heavier metals are inadequate for the required performance.

come into operation in 1942. Large increases in productive capacity were also made by the Canadian industry (also with government assistance), so that during the years 1940 to 1945, inclusive, the Canadian plants made over 36% of the greatly enlarged North American production.

Primary production capacity in the United States was increased six-fold, from 181,000 tons per annum in 1939 to 1,162,000 tons in 1943, as compared with a 10% increase in the steel industry and 50% in the copper industry. The rate of increase in actual production was great enough so that at no time was there any real shortage of aluminum for military purposes, although for several years there was very little aluminum available for civilian use. The final capacity was in excess of military needs; some of it, in uneconomic locations, was never put into operation.

The peak production of war years had been made possible only by the use of expensive standby or marginal power. Consequently, when the war ended, four of the government-owned reduction plants were permanently closed because they were economically noncompetitive, and five more were temporarily closed until they could be sold or leased. With the greatly increased competitive capacity and the tremendous amount of war scrap available to produce secondary metal, predictions were freely made that aluminum would be a drug on the market. The military and aircraft demand, which had taken about 90% of the wartime production, was reduced to nearly zero,

but the backlog of civilian needs, shortages of other metals, and widespread fabricating experience with aluminum obtained during the war period, combined to produce such an increased demand as to consume the accumulated scrap and current production within a couple of years. A world shortage of aluminum developed! In spite of extensive importations, American consumers' demands could not be met, and customers had to be placed on voluntary allocation during 1948. It is hoped that this situation may be relieved during the coming months.

In the allocations necessary in 1948 for fair play, every effort was made to take care of established uses and old customers, and to avoid introducing the metal into new uses where it was normally uneconomical and only temporarily desired because of the unavailability of some other metal. Many promising new uses have been held in abeyance (or developed on a strictly limited scale) because of the metal shortage; so that with any easing in the metal situation, the aluminum industry should be in a position to actively cultivate many new fields where it has economic advantages over its competitors.

Fig. 2 — Aluminum Production Capacity in U.S. as of Jan. 1, 1949, Totals 642,615 Net Tons

Alcoa, Tenn.	216 %			
	7 3.7%			
Badin, N. C.				
Massena, N. Y.	90%			
Niagara Falls	3.1%			
Vancouver, Wash.	132%			
Total, Alcoa	506%			
Lister Hill, Ala.	78%			
Longview, Wash.	3 48%			
Jones Mills, Ark.	5.6%			
Troutdale, Ore.	112%			
Total, Reynolds	294%			
	Legend:			
Spokane, Wash.	Plants Owned			
Tacoma, Wash.	3.2%			
Total, Permanente	20% Plants Leased From U.S.A.			
Total, U. S.				
	0 20 40 60 80 100 Per Cent			

Table I — World Production of Primary
Aluminum Ingot

(No Russian figures available)

COUNTRY	1939	1947
United States	163,000	494,000
Canada	82,600	297,000
France	57,800	58,700
Germany	215,000	None
Italy	37,600	11,700*
Great Britain	27,500	32,400
Switzerland	30,800	22,000
Norway	34,400	23,900
Others (except Russia)	9,700	8,300*
Totals	658,400	948,000 net tons

*1946 figures.

Capacity for Magnesium Ingot

Magnesium underwent an even greater percentage expansion, chiefly because of its use in incendiary bombs. A much larger proportion of the plants built were uneconomical, either because of their location and raw material costs, or because of the type of process employed. Under the stress of the war emergency it was necessary to choose (for many of the plants) a process which permitted quick construction and required a minimum amount of new electric power. Location therefore gravitated toward unused or nonstrategic power already developed. The thermal reduction plants were unable to go far enough in the development and improvement of their process and equipment to compete with the older electrolytic process.

Except in aviation, wartime uses of magnesium did not have a very great effect in improving or broadening the peacetime market. Thus, the recovery of magnesium production since the war, under the handicap of a large metal stockpile, has been quite slow. The aluminum shortage has impelled the light metal industry to divert as much business as possible from aluminum to magnesium, but inherent technical difficulties have limited this diversion in spite of the large amount of idle capacity for producing primary magnesium economically. Progress has, however, been sound and steady, and the magnesium industry looks forward to an increasingly bright future.

The changes in the magnitude and distribution of the world production of aluminum, brought about by the war, are shown in Table I, which compares the 1939 and 1947 production figures of the different countries. In preparing for the war, the German industry (largely owned by the German government) had pushed its output up to 34.2% of the world production by 1939. In 1947 German plants made no primary metal, but a small amount of production was reported in 1948.

Table II - Aluminum Distribution by Industries

(Alcoa shipments, 1946 to 1948	inclusive)	
To Fabricators	25%	
Building products	18	
Transportation	14	
Cooking utensils	10	
Household appliances	7	
Power transmission	6	
Machinery	5	
All others	15	

The United States production increased from about $25\,\%$ of the world total to about $52\,\%$, while the Canadian production increased from $12.5\,\%$ to a little over $31\,\%$ of the world total. The dominant position of the North American industry is clearly apparent.

Disposal of American War Plants

After the war was over, the government refused to sell or lease to Aluminum Co. of America any of its economically operable aluminum plants which Alcoa had built without profit. Instead, two of these plants were leased to the Reynolds Metals Co. and two to the Permanente

Reynolds' capacity to 31.4% and reduce that of Permanente to 18% of the total United States production.

Channels of Consumption

Metal products are generally classified as either wrought or cast. Figure 3 shows this classification for aluminum products for the years 1942 to 1948, inclusive, whether derived from primary or reclaimed metal. It will be noted that 20 to 25% of the market for finished aluminum products is in the field of castings. These are largely made of secondary metal and comprise sand castings, permanent and semi-permanent mold castings, and pressure die castings. The wrought products include sheet and plate, rod, bar and wire, forgings, structural and architectural shapes, tubing and foil.

A market analysis (Table II) based on Alcoa's shipments of aluminum products for the years 1946 to 1948 inclusive shows that the largest amount went to fabricators for further processing (25%), while the construction and transportation industries together took nearly one third of the shipments. Instead of the 2000 uses of 1938 there are now more than 4000 known.

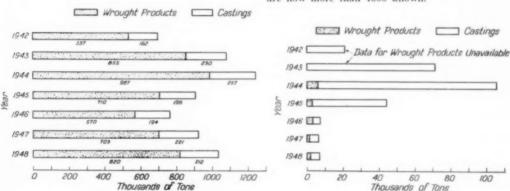


Fig. 3 and 4 — Shipments of Aluminum and Magnesium Products, Respectively, From U.S. Mills and Foundries, 1942 to 1948

Metals Corp. The resulting distribution of capacity in the United States as of Jan. 1, 1949, is shown in Fig. 2. Since then, the Niagara Falls plant has been permanently closed and Alcoa is constructing a 57,000-ton plant near Port Lavaca, Texas, which is slated to start production toward the end of 1949. The Reynolds Metals Co. is reported to be making arrangements for additional power at Jones Mills, which will double the capacity of that plant. The net result of these changes when they are completed will be to increase

Figure 4 shows the distribution of United States shipments of magnesium products from 1942 to 1948. Figures for wrought products in the first two years are not available, but if known probably would be of the general order of those in 1945 and 1946. Sand castings, permanent and semi-permanent mold castings and pressure die castings supplied most of the business during the war years, but the production of sheet, plate, extrusions and tubing makes up more than one third of postwar production. The limited resist-

ance to corrosion (which interfered with the use of magnesium in the earlier years) has been largely overcome, foundry technique has been improved, and the cost of making both castings and wrought products decreased in recent years. The excellent machinability of magnesium is a very useful characteristic to supplement its low density (one fourth that of iron), in its bid for markets.

Present Competitive Situation

The present production of aluminum is limited by the lack of available power at a suitably low cost. Many million more pounds would have been made and sold in 1948 if more power had been available. Contrary to many statements, the ore situation is excellent. Ultimately it is unlimited. There is about twice as much aluminum in the earth's crust as there is iron, and the supply of magnesium in the ocean and in the dolomite and magnesite deposits is simply tremendous.

The cost of the necessary chemical treatment of the ore, and the higher cost of labor involved in the relatively small production units are unfavorable factors in comparison with iron and steel. In contrast with a 1000-ton blast furnace, a large aluminum electrolytic cell (absorbing 50,000 amperes of electrical current) produces about 750 lb. (repeat, pounds) of aluminum per day. It is clear, therefore, that the competition of aluminum and magnesium with iron and steel must be based on special physical and chemical properties, rather than merely on price per pound.

In competition with the other nonferrous metals, the light metals are on a much more favorable cost basis. Actually, the *volume* of aluminum produced and sold in 1946 to 1948 was greater than that of any other nonferrous metal.

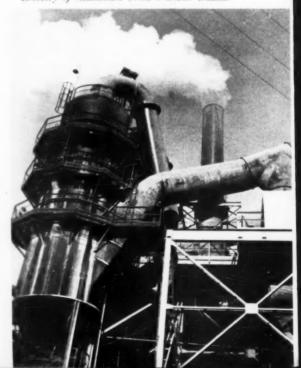
As compared with iron and steel, the light metals are characterized by a low modulus of elasticity, high thermal and electrical conductivity, and excellent resistance to corrosion under most conditions. Their much lower melting point involves a more rapid loss of strength at moderately elevated temperatures, but when the temperature is reduced they continue to increase in both strength and ductility down to liquid air. At -320° F, the increases in tensile strength and elongation range from 10 to 100%, depending on the alloy and temper.

The reduction in strength at elevated temperatures is not an unmixed disadvantage, for it favors the manufacture of complicated shapes of even the strongest alloys by extrusion at temperatures where dies of special steels are still strong enough to withstand the necessarily high pressures. Such shapes have opened up large markets for both aluminum and magnesium. It is also the low melting point of these metals which enables the production of pressure die castings and permanent mold castings, using steel molds, and it facilitates the production of sand castings.

With their total world production of only about one million tons per year, the light metals are obviously not a serious threat to steel tonnage, although they compete with and take business from steel in certain special fields. In the nonferrous field, the fact that aluminum and magnesium producers have been able to reduce their prices during the war years, while their competitors have had to increase theirs, places the light metals in a very much more favorable competitive position. The prospects for continued growth of the light metal industry seem, therefore, to be good.

The principal present obstacle to such growth is the shortage of suitable low-priced electric power for the production of the increased amounts of metal which seem sure to be needed. The intensive research and development work which the light metal industries have had to do, in order to develop to their present status, gives them a good background of information and experience on which to base further progress and growth in the highly competitive metal markets of the future.

Fig. 5 — One of Seven Towers for Scrubbing Gas From Kilns in Plant Erected by Alcoa to Improve Recovery of Aluminum From Wartime Bauxite



Critical Points

By the Editors

Chemical and Metallurgical Engineering

D^O your corrosion tests get fouled up because the glass beaker dissolves faster than the metal specimen? Probably not. But that's what happens when tantalum is immersed in some acids. This information comes from L. F. Yntema, director of research for Fansteel Metallurgical Corp., who recently showed us the workings of Fansteel's plant in North Chicago. Dr. Yntema is not especially interested in the corrosion of glass, but he is concerned with the chemistry and metallurgy of tantalum, columbium, tungsten and molybdenum.

(Just now, the fabrication of molybdenum is receiving considerable attention. R. W. Yancey, chief metallurgist, exhibited an 8-ft. length of ½-in, molybdenum tubing drawn down to 0.030-in, wall; and a 2-in, tube with ¼-in, wall, 43 in, long, has been made by hot extrusion.)

Tantalum, used in electronics and in chemical equipment, melts at 5425° F. It is also refractory in the sense that it is difficult to refine. The winning of tantalum at Fansteel involves crushing the concentrated ore, dissolving it in molten caustic soda, leaching, washing, digesting in hot HCl, decanting, dissolving in HF, filtration, evaporation, crystallization, drying, dissolving in fused salt, electrolysis, grinding and drying. All this to get tantalum powder for processing by the metallurgical department. Throughout these chemical operations, control is directed toward obtaining final powder of a size and purity that will satisfy the metallurgical requirements of pressing, sintering and fabricating. Where else could be found such close harmony between chemical and metallurgical engineering?

Where else? Well, in Chicago, the next day, at the Illinois Institute of Technology we witnessed the dedication of a new building for Metallurgical and Chemical Engineering. Here also the two sciences are close together. (But here the product of the Chem. Engr. Dept. doesn't go to the Met. Dept. for final molding and polishing!) We admired the simple, functional beauty of the new building, and observed that the metallurgical

students and faculty, under the direction of Prof. Otto Zmeskal, have done a lot of work there already. Also noted that the principal administrative offices of the Institute are on the same floor as the classrooms and laboratories of the Department of Metallurgical Engineering. Whether in a technical institute or an industrial plant, it's good to see a close relation between metallurgy and management. Metallurgy and management—the phrase has a nice lift to it!

Taxes Versus Wages

AS Timken Roller Bearing Co. celebrates its 50th anniversary by escorting thousands of customers and other friends through its properties at Canton and Gambrinus, Ohio, it is evident that the management is willing to let the plants speak for themselves as the source of excellent mechanical bearings, and spends its efforts in impressing the visitors with one important business fact that could only be conveyed by placards erected at every turn and stencilled on the pavements:

FEDERAL INCOME TAXES ARE PRETTY HIGH \$58,179 Each Day to Washington

Numerous signs in various departments bring the matter home more directly. Thus, over a battery of reheating furnaces in the blooming mill:

These furnaces are out-of-date and need replacing. A modern installation would cost \$350,000. That represents our Federal taxes for six days. We are not financial magicians — we can't have both.

Even the most casual inspection by a technologist reveals the large number of ingenious automatic feeding devices at various machines. We were told of a pilot plant at Bucyrus, Ohio, where the necessary machine tools are so interlinked that the bearing parts are hardly touched by human hands from the time the bars are fed into the automatics until the mailman calls for the sealed, addressed and stamped package!

Labor saving, in the steel melt shop, has also gone to the extent that all brick, electrodes, and packaged ferroalloys are racked on pallets by the shipper (or palletized as unloaded) and handled at Canton in jig time by lift trucks. Harry Walther, melt shop superintendent, during a privately conducted side-trip pointed out the improvements resulting when electric furnace roofs are built of special shapes exclusively. The 12-in. brick that constitute the haunches of the dome are all "keys"—tapered in two directions and accurately curved to fit the adjoining rings. The crown, containing the three electrode-holes, is of deeper blocks, each one accurately shaped according to definite plan so that the top area is

flat and horizontal, for close fit to the electrode coolers. A dome of this sort for a 25-ton Heroult furnace can be fitted by two men in one day (one third the time required to scutch "standard" bricks to fit). Such roofs, laid dry, need no long drying period; their life is increased about 20%.

Another point: Walther believes that silica dust raised in handling dry brick causes silicosis, so all silica brick are oiled — a practice he thinks is worthy of adoption by the brickmakers.

Observations at Pratt & Whitney Aircraft

WHAT does a "Chief of Engineering Operations" do? It's a rather unusual title, and Paul Eddy (one-time member of Metal Progress's editorial advisory board), who now holds that position at Pratt & Whitney Aircraft's enormous engine plant at East Hartford in Connecticut, spent most of a day explaining and exhibiting his domain to the editor. It requires about 4000 men, one quarter of the entire working force, for administration, materials control and development, inspection, and manufacturing and testing experimental engines and parts (either variants of engines in production or entirely new designs). Experimental manufacturing is completely integrated and in itself is equivalent to a plant of more than average size. . . . Design of engine parts is so refined and stress analysis is so difficult that a great variety of testing machines are devised for parts, subassemblies and engines, ranging all the way from rotating beam machines for conventional fatigue specimens, through dynamometers attached to gear trains, to a multimillion-dollar laboratory for testing compressors for jet engines. (Work does not stop here, for United Aircraft Corp., Pratt & Whitney's parent, operates a wind tunnel, and a modern airfield, the home of various flying "laboratories".) Instrumentation on many of these subassembly tests is so complete that wiring and hydraulic connections resemble a model of the human nervous system.

Pratt & Whitney Aircraft, immediately after the war, brought back to East Hartford the activities remaining in its scattered wartime units. After years of development, production was just getting under way on the "Wasp Major" engine with 28 radial cylinders ranged in four banks and developing 4000 hp.—just what the doctor ordered for the long-range high-speed bombers. Alongside this production line, room had to be made for manufacturing and rebuilding several other successful smaller models. Also the jet engines had appeared. It was a busy year of reconversion at East Hartford! Making an Ameri-

canized version of Rolls-Royce's Nene gas turbine introduced the personnel to numerous entirely new metal working operations, especially in fabricating sheet metal combustion chambers and exhaust cones of hard, heat resisting alloy. (As a footnote about time as an essential factor, it may be said that it took this energetic organization just 18 months to redesign, qualify by test, and produce its first jet engine — 18 months occupied in reworking 1200 drawings to American standards and practices and making 1000 design changes, rearranging five acres of shop and installing 260 new machine tools, building or buying 5300 jigs, dies, gages, and portable tools, and making and assembling the 1100 varieties of parts.)

A set of assembly operations on the Wasp cylinder, timed like a ballet figure, was especially interesting. A thin, marvelously accurate steel liner is slipped into a finned aluminum muff and screwed into a forged aluminum head; the valve seats, valve guides, rocker shaft bushings and exhaust connector are set in place. All these parts are either heated or refrigerated, the temperatures and clearances being carefully adjusted to avoid undesirable aging effects in the aluminum alloys or tempering of the heat treated steels.

The major engine parts of aluminum are now made of forgings rather than castings, thus avoiding many rejects for foundry defects. Furthermore, in cylinder heads and muffs, more and thinner fins can be cut into a radiating surface than can be cast into it. . . . The cutters are the only ones ever seen by this observer made of cast iron, no less. The thin disk, carrying four carbide inserts, operates at very high speed; the good damping characteristic of cast iron minimizes tool breakage. . . . Going the West-Coast engineers, who discovered rubber dies, one better, aluminum parts are formed in a "hydrostatic" die, wherein water forces the sheet, sealed around the edges, into a shaped die-cavity. Thin coatings of adherent plastic not only prevent scratches on the aluminum sheet but seem to lubricate the dies.

One wonders where the ideas for new engines come from — other than improvement, detail by detail. There is, of course, the urge in all the upper management echelons coming from the realization that no engine exists but can be improved. Next there is an obligation to visualize the future requirements of the air age, and be ready to supply them. New engines must also be prepared to meet new specifications set by the Air Forces for advanced planes. Finally, at intervals a rare genius appears (like Frank Whittle) with the ability to design and construct a model of a radically new machine, and the drive to get it from the experimental stage to the point of complete development.

By John Chipman Professor of Metallurgy Massachusetts Institute of Technology Cambridge, Mass.

Another Look at the Problem of Steel Deoxidation

STEELMAKING, from the chemist's viewpoint, is a succession of oxidations and reductions. At the very start, iron oxide of the ore is reduced by carbon in the blast furnaces, and several other elements are also reduced along with the iron. These and the excess carbon must be removed in the openhearth by oxidation, and, finally, the unavoidable excess oxygen must be reduced. This last step is called deoxidation. There are several reasons why deoxidation is necessary, which very briefly may be stated as follows:

 To stop the carbon-oxygen reaction so as to hold carbon at a desired level.

2. To keep this reaction stopped or controlled so that, on freezing, no gas is evolved—or the right amount of gas is evolved to produce the desired kind of ingot.

To control certain properties of the finished steel.

In practice, deoxidation is accomplished by the addition of various substances called deoxidizers. These are all elements whose oxides are more stable than iron's. The addition of such an element may affect the oxygen in the metal either by diminishing the amount dissolved in the steel, or by rendering that which is present less active. In the early development of deoxidation theory, it was only the first of these effects which was seriously studied, and it is unquestionably true that the actual removal of oxygen from the bath is the major function of all deoxidizers. But recent investigations have also shown that the second effect cannot be overlooked, because the presence of certain elements may have a pronounced effect upon the activity of the oxygen which remains in solution in the steel bath. The first effect is simple and straightforward, and is predictable from thermodynamics. In a qualitative way, the second effect was predicted by Zapffe and Sims1 in their discussion of monoxides in steel. It is not well understood, however, and quantitative data are scarce and have only recently become available.

It is the recognition of this second aspect of deoxidation which requires that we take a careful second look at the subject. It is not sufficient to know that addition of a given element will diminish the oxygen content of the steel. We must also give thought to the behavior of the oxygen which remains dissolved in the steel bath, for the presence of the deoxidizer may seriously interfere with the normal activity of this residual oxygen.

Deoxidation With Hydrogen - Let us consider the very simplest case of the deoxidation of steel by hydrogen. I call this the "simplest" because both the deoxidizer and the product of deoxidation are gases, and gases are fundamentally simple substances. The deoxidizing power of hydrogen has been studied by bringing liquid metal into equilibrium with a known mixture of hydrogen and water vapor, then cooling the metal and analyzing it for oxygen. The experimental arrangement which Mars Fontana2 and I used for doing this about 15 years ago consisted of a small crucible containing approximately 2 oz. of liquid iron which was held at temperature by highfrequency induction in a stream of hydrogen containing a known proportion of water vapor. (Induction heating also stirs the metal, so the gases had an opportunity to do their oxidizing or deoxidizing very rapidly.) When the oxygen content reached a constant level, the crucible was lowered into the cold part of the tube furnace

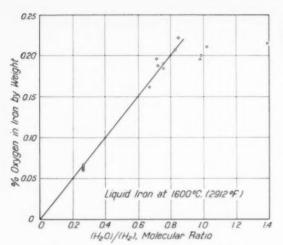


Fig. 1 — Oxygen in Liquid Iron at 1600°. C Has a Direct Proportion to Ratio of Water Vapor and Hydrogen in Contact With It, up to a Content Representing Saturation (About 0.22%)

(or quenched), and the little ingot analyzed for oxygen.

Results of these experiments are shown in Fig. 1, where the oxygen content of the metal at 1600° C. (2912° F.) is plotted against the ratio of water vapor to hydrogen. (These early results have recently been exactly confirmed by Minu Dastur in my laboratory using a mixture of water vapor and hydrogen diluted 4 to 1 with argon.) At a given temperature, therefore, the ratio of the partial pressure of H2O to that of H2 precisely determines the oxygen content in the iron at 1600° C., so long as we are dealing with pure liquid iron, not yet saturated. It should be noted that the line of Fig. 1 terminates at about 0.22% which, according to measurements of Karl Fetters and Charles Taylor,3 represents the limit of solubility of oxygen in pure iron at 1600° C.

The Law of Mass Action

Hydrogen is of no practical use in the deoxidation of steel. The data of Fig. 1 are of interest only because they show how oxygen behaves when it is dissolved in liquid iron. The mixture of water vapor and hydrogen is useful because it is adjustable over a wide range of oxidizing or deoxidizing power and may be used as a yard-stick of deoxidation. The results of Fig. 1 also apply to a condition of equilibrium: this means that they represent the limiting condition of deoxidation obtainable with a given gas com-

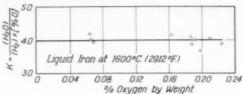


Fig. 2 — Equilibrium Constant K for Experiments of Fig. 1

position. We shall want to know the limiting oxygen content obtainable with a given deoxidizer, and for this purpose, it is necessary to apply the laws of chemical equilibrium.

The "Law of Mass Action" has been in use for over 100 years. It tells us that for equilibrium at any given temperature we may express the concentrations of the reacting substances in the form of a constant ratio called an equilibrium constant. For deoxidation with hydrogen we may write:

$$\mathbf{H}_{2}(\mathbf{gas}) + \mathbf{O} = \mathbf{H}_{2}\mathbf{O}(\mathbf{gas}); K = \frac{(\mathbf{H}_{2}\mathbf{O})}{(\mathbf{H}_{2}) \times [\Im \mathbf{O}]}$$

where the symbols in parentheses () represent the partial pressures of the gases, and the symbols in brackets [] the weight per cent. The bar under O indicates that the oxygen is dissolved in liquid iron. The fact that K is actually constant in these experiments at 1600° C. is shown in Fig. 2.

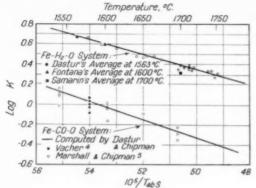
Effect of Temperature — The change in equilibrium constant with temperature has a very important application in studying the formation of nonmetallic inclusions during the cooling and solidification of steel in the mold, even though we shall not have time to discuss it during the present lecture. We must be content here with an indication of the general nature of such temperature effects, using the top line of Fig. 3 as an illustration from the recent results of Minu Dastur on deoxidation with hydrogen.

Deoxidation With Carbon Monoxide

The action of carbon monoxide is as simple as that of hydrogen, so long as we consider only metal low in carbon. Using the same notation as above, the reaction and its equilibrium constant are:

$$CO(gas) + \underline{O} = CO_2(gas); K = \frac{(CO_2)}{(CO) \times [\%O]}$$

The first such study was made by H. C. Vachers some 15 years ago. The effects of pressure and temperature were investigated by Shadburn Marshall. Both series of results on very low-carbon metal are shown by the points in the lower portion of Fig. 3. The line was calculated from



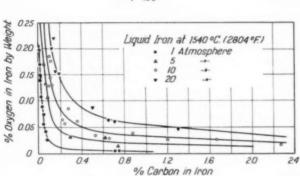


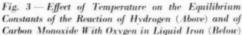
Fig. 4 — Results of Experiments by Marshall and Chipman on Equilibrium in Liquid Iron at 1540° C. (2804° F.), Between Carbon and Oxygen at Various Pressures

Dastur's work, using the known thermodynamic properties of the gases. The good agreement means that this second yardstick of deoxidation agrees with the first.

Deoxidation With Carbon

"Boiling" the bath in openhearth refining is decarburization with oxygen or deoxidation with carbon, depending upon the point of view. In the openhearth this reaction never gets to equilibrium, but in other practices it may, as shown by John Marsh⁶ for the basic electric. The equilibrium was studied by Shadburn Marshall⁵ using a small induction furnace designed for operation at pressures up to 20

Fig. 5 — Relation of [% C] × [% O] and [% C] at Various Pressures. According to older theory, all lines should be horizontal



atmospheres or 300 psi. His experimental results are shown in Fig. 4, with smooth curves drawn for averages.

On the basis of the law of mass action we may write: $[\%C] \times [\%O]$

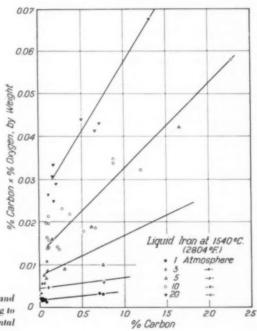
 $CO(gas) = C + O; K = \frac{CO}{CO}$

This requires that for a given pressure of carbon monoxide the product $\%C \times \%O$ (both factors representing weight per cent in the iron) should be constant. The actual results are shown in

Fig. 5. Instead of being constant, the product rises sharply with increasing carbon; furthermore, the higher the pressure, the sharper is the rise.

The results clearly violate the law of mass action.

Activity Coefficient—The embarrassment of having a variable constant on his hands is nothing very new to the physical chemist. It has been well known for more than 50 years that the law of mass action (in the simple form that I have used here) is at best an



IN his opening remarks to this First Andrew Carnegie Lecture before the Pittsburgh Chapter , on a subject regarded as quite scientific by most metallurgists, Dr. Chipman aptly quoted from Carnegie's "Autobiography":

Looking back today it seems incredible that as recently as 1870 chemistry in the United States was an almost unknown agent in connection with the manufacture of pig iron. It was the agency, above all others, most needful in the manufacture of iron and steel. The blast furnace manager of that day was usually a rude bully, generally a foreigner, who in addition to his other acquirements was able to knock down a man now and then as a lesson to the other unruly spirits under him. He was supposed to diagnose the condition of the furnace by instinct, to possess some almost supernatural power of divination, like his congener in the country districts who was reputed to be able to locate an oil well or water supply by means of a hazel rod. He was a veritable quack doctor who applied whatever remedies occurred to him for the troubles of his patient.

Carnegie found the chemist he wanted in the person of

..... a learned German, Doctor Fricke, and great secrets did the doctor open up to us.... Nine tenths of all the uncertainties of pig-iron making were dispelled under the burning sun of chemical knowledge.

approximation. In order to write an equilibrium constant that is really a constant, we must use a quantity called the activity, which is frequently but not always equal to the concentration. In other words, we must introduce a correction factor called an activity coefficient which shows the ratio of the real activity to the percentage of the material present. Calling this coefficient f, an exact statement of the law of mass action for deoxidation with carbon is:

$$K = \frac{[\text{Activity of C}] \times [\text{Activity of O}]}{|\text{Pressure of CO}|}$$
$$= \frac{[f_{\text{C}} \% \text{C}] \times [f_{\text{O}} \% \text{O}]}{(\text{CO})}$$

Careful analysis of the data indicates that $f_{\rm C}$ does not differ much from unity except at carbon

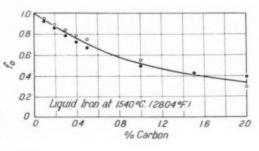
Fig. 6 — Activity Coefficient for Oxygen; Open Circles Have Been Computed From Marshall and Chipman's Work⁵ Shown in Fig. 5; Closed Circles Have Been Computed From CO₂/CO Ratio concentrations higher than 1%. On the other hand, f_0 is much affected by the presence of carbon, as shown in Fig. 6. Here, the open circles are average points computed from the lines of Fig. 5, while the solid circles are computations for the activity coefficient of oxygen based on the same experiments but calculated from a secondary yardstick—namely, the ratio CO_2 CO. This figure is just a graphical method of showing that in the presence of carbon the activity of a given percentage of oxygen is less than it would be in the absence of carbon.

This is a manifestation of the second aspect of deoxidation noted at the outset. The addition of carbon to the bath not only reduces the quantity of oxygen remaining, but also renders less active that which remains. In the case of carbon, the effect is relatively small in the mild and medium steels — and, in fact, escaped detection until experiments at elevated pressures were conducted.

Before examining the effects of other elements, let us consider briefly the question of what causes oxygen to become less active when carbon is present.

Constitution of Liquid Steel

No one has ever seen an atom of iron, and I shall not attempt to show you what one of them looks like. Nor can I draw for you a picture showing details of the arrangement of atoms and electrons in liquid iron. The sketches which I want to show you are an attempt to represent in two dimensions the essentials of the three-dimensional arrangement of atoms in liquid steel. In Fig. 7 the atoms are all alike and all are iron. They are not regularly arranged as in a crystal, yet this is not an entirely random arrangement. It is not a shotgun pattern, since no two atoms occupy the same space. There are only



a few points where two atoms come very close together or where a very wide vacancy exists. Certain forces of attraction and repulsion maintain an average distance between atoms. Since the atoms are in motion, each undergoes a continual change of neighbors and of distances between neighbors. This picture is based upon various kinds of evidence, including actual X-ray measurements of mean distances between neighboring atoms in metals of lower melting point.

Exactly how an atom of carbon or of oxygen fits into this arrangement is less clearly understood. In Fig. 8 I have attempted to depict two alternative ideas. On the left, each carbon atom (represented by a small black circle) is bonded to three iron atoms forming the molecule Fe₃C. Each oxygen atom (represented by a small open circle) is combined in the molecule FeO. In a limited number of places, a carbon and an oxygen atom may form a molecule of CO.

In the arrangement shown on the right of Fig. 8 each carbon is bonded to all of its surrounding iron atoms. The bond strength falls off with distance so that only nearest-neighbor atoms are effective. Each oxygen is similarly bonded to its

Startled True Dimensional Represen-

Fig. 7 — Simplified Two-Dimensional Representation of Atomic Arrangement in a Liquid Metal

nearest-neighbor iron atoms. When carbon and oxygen atoms come close together, they may share the bonding of nearby iron atoms, and the carbon-oxygen bonding may also become effective; in the resulting complex, it is clear that both carbon and oxygen are held more firmly than when bonded to iron alone, and the activity of each is reduced in proportion to the number of such complexes. In a steel of high carbon and low oxygen content, a small fraction of the carbon atoms may thus reduce the activity of a large fraction of the oxy-

gen. Thus, the activity coefficient of oxygen is strongly reduced by the presence of carbon.

These two alternative pictures of the liquid structure serve equally well in interpreting the equilibrium data that have been obtained. Insofar as thermodynamics is concerned, either may be right or both may be wrong; it is the actual data that count, such as represented by the curve of Fig. 6. This was my view at the time that Shadburn Marshall and I published our results on the carbon-oxygen equilibrium. For simplicity, we adopted a method of calculation based on the left-hand part of Fig. 8, since it seemed this would be more easily understood. Subsequently, it has become evident that it is also more easily misunderstood, and I am ready to abandon it in

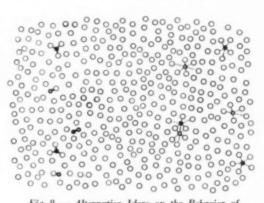


Fig. 8 — Alternative Ideas on the Behavior of Carbon Atoms (Small Black Circles) and Oxygen Atoms (Small Open Circles) in Liquid Steel. At the left are shown Fe₅C, FeO and CO molecules; at right, carbon and oxygen are bonded to nearest iron atoms. The arrangement at the right seems more probable than the one at the left

favor of concepts illustrated on the right. This provides an oversimplified picture which will require modification with the further development of the electronic theory of alloys, but it is adequate for the present discussion.

Deoxidation With Chromium

Chromium is not much of a deoxidizer, and this makes it rather useful for study. Oxygen contents of the liquid iron-chromium alloy, even in the presence of 10% chromium, are still high enough to be determined by the ordinary vacuum fusion method with a good degree of accuracy. Furthermore, the method which Henry Chen⁷

used in my laboratory to study the deoxidizing power of chromium will also be applicable to some other elements.

Iron-chromium alloys were melted in an atmosphere of known oxidizing power, consisting of a controlled mixture of water vapor and hydrogen in just such an apparatus as Fontana had used 10 years earlier for pure iron. Using crucibles of either chromic oxide or of the mineral chromite, the hydrogen begins to reduce the oxide if the gas is low in water vapor, thus adding chromium to the metal bath. If the hydrogen is high in water vapor, it oxidizes some of the chromium already in the metal. Under equilibrium conditions, the chromium content depends upon the ratio $(H_2O)/(H_2)$, as shown in Fig. 9 in the Data Sheet, p. 216-B.

Using alumina crucibles, it was possible to work under conditions that were not sufficiently oxidizing to form chromic oxide (Cr_2O_3) but were oxidizing enough to put considerable oxygen into the bath. The results are shown in Fig. 10 in the Data Sheet. Here, it is important to note that a given ratio of $(H_2O)/(H_2)$ represents a constant oxidizing potential—a constant activity of oxygen. It is evident that the percentage of oxygen in the metal corresponding to a given activity becomes greater as the chromium content increases. In other words, the activity coefficient of oxygen decreases as chromium increases (Fig. 11).

The straight lines of Fig. 10 terminate on the formation of a separate oxide phase. The length of each line is fixed by Fig. 9, and results at several levels of chromium and at 1595° C. (2900° F.) are shown in Fig. 12, lower left in the Data Sheet, p. 216-B. The long diagonal represents the oxygen content of pure iron; it also represents the activity of oxygen in any of the alloys as a function of the ratio $({\rm H_2O})/({\rm H_2})$. The % oxygen in each of the alloys is shown by a short straight line terminating in an enveloping curve which shows the maximum oxygen in the molten alloy at any chromium content.

This figure demonstrates the two aspects of deoxidation. If chromium merely decreased the amount of oxygen present, the results would appear as a series of points on the line for pure iron. The secondary effect, a decrease in activity of the remaining oxygen, puts the results on the upper curve.

The same data are shown again in Fig. 13 (p. 216-B) as a logarithmic deoxidation chart. The upper line represents the maximum percentage of oxygen in equilibrium with chromium at 1595° C. (2900° F.), and is the same as the upper envelope of Fig. 12. The lower line is the activity of this oxygen. At 10% chromium, for

example, the oxygen content is actually 0.028% by analysis, but it behaves chemically as if it were only 0.011%. Its activity coefficient I_o is 11/28 or 0.4, which means that it has only four tenths of the oxidizing power (for reaction with hydrogen or carbon) that a like percentage of oxygen would have in pure iron.

Interpretation of Results

These experimental results could be interpreted on the assumption that the oxygen is present in part as FeO, and in part as CrO. Such an explanation leads to equations which fit the experimental data as well as could be expected. If we are going to say that oxygen in pure iron is FeO, then it is reasonable and consistent to say that the extra oxygen in iron-chromium melts is CrO. I feel, however, that these concepts are capable of getting us into more trouble than they will ever get us out of. It seems safer to speak simply of dissolved oxygen, and if we wish to distinguish between the excess oxygen which is present on account of the chromium and that which would be associated with the iron only, under similar conditions, we may refer to them respectively as Oc, and Open

Let's take a look at the possible atomic arrangements in the liquid metal containing iron, chromium, and oxygen. In the lower right corner of the Data Sheet, p. 216-B, the circles in Fig. 14 that carry a cross represent chromium atoms, the open circles iron, the small circles oxygen. In the top portion of the diagram are shown three oxygen atoms, one surrounded by chromium, the other two by iron atoms. In the bottom portion are shown three oxygen atoms, each (on the average) one third surrounded by chromium.

I doubt that it would be possible to prove that either one of these arrangements is correct, but certainly the lower arrangement is far more probable. In either event, we would say that one third of the oxygen present is Ocr, the remainder OFe. This corresponds to the nomenclature which Chen and I used in discussing this system in @ Transactions three years ago.7 It should be noted here that the sketch, Fig. 14, illustrates the results of a stronger chemical bonding between chromium and oxygen than between iron and oxygen. For, while only about one atom in 12 throughout the solution is chromium, one out of three is chromium in the groups surrounding the oxygen atoms. This would mean that the activity of oxygen is reduced to two thirds its normal value, or $f_0 = 0.67$. It is equivalent to saying that one third of the oxygen present is Ocr.

(Continued on p. 217, beyond insert)

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August, 1949; Page 216-A



By John Chipman

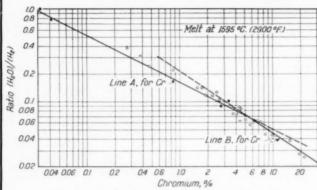


Fig. 9 — Equilibrium in the Reaction of Hydrogen Plus Water Vapor With Chromium in Liquid Iron at 1595° C. (2900° F.). Line A represents equilibrium with chromite, line B with chromic oxide

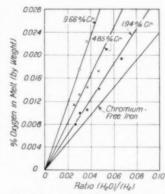


Fig. 10 — Relationship Between % Oxygen and the Batio (H₂O)/(H₂)

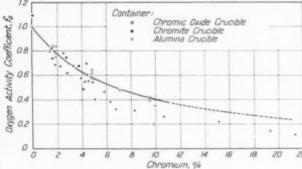


Fig. 11 — Effect of Chromium in Iron-Chromium Alloys Upon the Activity Coefficient of Oxygen

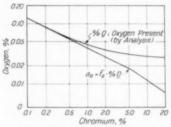


Fig. 13 — Deoxidation Diagram for Chromium at 1595° C.

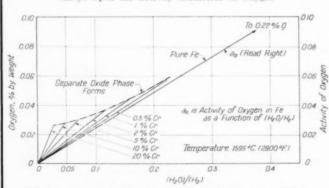


Fig. 12 — Oxygen Concentration at Several Chromium Levels. The activity of oxygen is given in the lowest line, which shows also its percentage in pure iron for any given gas composition

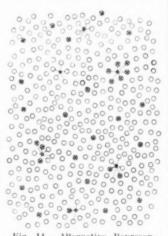


Fig. 14 — Alternative Representations of the Arrangements of Atoms in Liquid Iron-Chromium-Oxygen Alloys. That in the lower portion is more probable

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Metal Progress; Page 216-D

Deoxidation With Manganese

Very little new information on manganese deoxidation has been published for 15 years, and our principal source of data is the German research of the early 30's. Körber's original results are probably too high, since his oxygen solubility under pure FeO slag was about 40% above values more recently reported. The curves of Fig. 15, from p. 496 of "Basic Openhearth Steelmaking",9 have been corrected for this. The deoxidation product is not simple MnO, but a slag containing FeO as well, and the ratios (MnO)/(FeO) are shown by the straight lines. Dotted portions are extrapolated into regions where the slag is partly solid.

There is no evidence that manganese affects the activity coefficient of oxygen in the bath; in fact, Körber's discussion indicates that it does not. The action of manganese is thus only to decrease the

amount of oxygen in solution in the iron. It should be noted that even the diminished percentage of oxygen is still large compared to normal openhearth operation. (In practice, the oxygen content is controlled by carbon at levels below that at which manganese has any effect.)

Deoxidation With Silicon—A considerable amount of study has been given to deoxidation with silicon, the best quantitative results to date being those of Körber and Oelsen. 10 Even these careful results leave much to be desired with respect to precision. They are shown in Fig. 16, taken from my 1942 Campbell Memorial Lecture. 10

0.30 3.0 25 0.25 % Oxygen in Metal (Curved Lines) in Siag (Straight 0.20 0.15 (MnOV/FeO) 0.10 10 05.9 0.05 0 0.6 0.8 1.0 12 Manganese, %

This article (begun on p. 211) summarizes 20 years of study of the reactions between metal and oxygen at steelmaking temperatures. Dr. Chipman believes that many discrepancies between the results of experiments and thermodynamic computations can be ascribed to the ability of an alloying element to share electrons with oxygen, as do the surrounding iron atoms, thus more effectually tying up the oxygen and reducing its activity. The net effect is the same as though a smaller amount of oxygen were actually present. A final diagram shows these relationships quantitatively for the common alloying elements in steel.

where the equilibrium constant is plotted against reciprocal temperature. The constant is defined by the equation:

$$SiO_2 = Si + 2O; K = [\%Si] \times [\%O]^2$$

In making the plot, I have discarded all data in which silicon or oxygen was below 0.006% (where analytical errors are likely to be large); even so. considerable scatter remains, and the solid line represents only an average best value. It is drawn with a slope corresponding to the known heat of the reaction. It should be noted that while the data cover a range of silicon from 0.006 to above 1%, there is no systematic shift of the constant with the silicon content. The variations in K are those due to accidental errors and do not indicate a specific effect of silicon upon the activity coefficient of oxygen. However, the data are not accurate enough to give a final answer on this point - an answer which will be obtained only by more careful experimental work.

Zapffe and Sims¹ were the first to point out that the oxygen activity might be seriously affected by the presence of silicon. They did not use the term "activity coefficient". Their hypothesis called for the formation of a lower oxide (SiO) and its solution in the liquid metal. If this occurs it must, of necessity, result in a decreased activity

Fig. 15 — Manganese-Oxygen Equilibrium Under FeO-MnO Slags Calls for Relatively High Oxygen in the Bath. In practice, the carbon in the molten steel keeps the oxygen so low that manganese has no effect^a

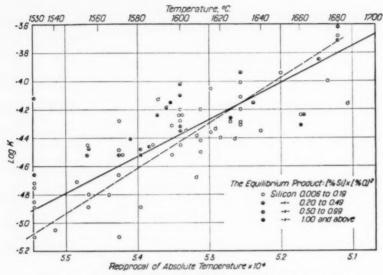


Fig. 16 — Experimental Data by Körber¹⁰ on the Silicon Deoxidation Constant $K = [\% Si] \times [\% O]^2$ at Various Temperatures. The heavy line represents most likely values for the logarithm of K (base 10)

coefficient. Their experimental efforts to prove the presence of SiO apparently suffered from two very severe handicaps: First, in the type of apparatus they employed, it seems very doubtful that any of their heats could have reached equilibrium, and second, oxygen analyses were lacking or inadequate. For these reasons, their results cannot be regarded as quantitative. Until more precise experimental results are available, our best

information is still that of Körber and Oelsen as shown in Fig. 16.

Expressed in more useful form, the average relationship between silicon and oxygen at several temperatures is shown in Fig. 17. It should be noted that these curves apply only in the presence of solid silica or of slags saturated with At very low silicon contents, the deoxidation product is a silicate slag, and deoxidation is slightly more complete than the curve would indicate. This small effect is scarcely perceptible except at silicon contents below about 0.02%.

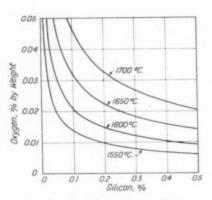


Fig. 17 — Equilibrium Between Silicon and Oxygen in Liquid Steel at Various Temperatures in Contact With Solid Silica or Slags Saturated With Silica

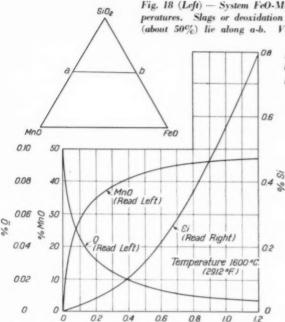
Deoxidation With Silicon and Manganese

When silicon and manganese are used simultaneously for deoxidation, the reaction product, under proper conditions, is a fluid ironmanganese-silicate slag. This product is very similar to acid openhearth slag. Some of the finest research that has been done in the entire field of steelmaking is that of Körber and his associates on slags of this type.10 They showed that the ternary system FeO-MnO-SiO2 may be divided into two fields, as shown in Fig. 18 by the line a-b which runs from 50% dissolved MnO to 50% FeO. Slags or

deoxidation products which are saturated with silica lie along this line and always contain about 50% dissolved SiO₂.

In the absence of manganese, the slag has the composition b. As manganese increases, its composition shifts toward a. This is shown in the curve marked MnO in Fig. 19. At the same time, the oxygen content decreases along curve O, while silicon increases along the line marked Si.

These curves give a fairly complete picture of the chemistry of simple acid slags saturated with silica at 1600° C. They also correspond to the deoxidation product and the degree of deoxidation when the ratio of silicon to manganese is fairly high. At lower silicon and higher manganese content, the reaction product lies below the line a-b in the range of very fluid slags. No data corresponding to this region have been published; experimental studies would be difficult, but the results would be interesting and probably important.



Deoxidation With Vanadium

% Mn

A very interesting study of the deoxidizing action of vanadium has just been completed in my laboratory by Minu Dastur.* Vanadium is of special interest because of the anomalies that have appeared in attempts to evaluate its deoxidizing

Fig. 20 — Oxygen in Iron-Vanadium Melts at 1600° C. For a given oxygen activity (as measured by the ratio $(H_2O)/(H_2)$, the amount of oxygen in liquid iron is increased by the presence of vanadium

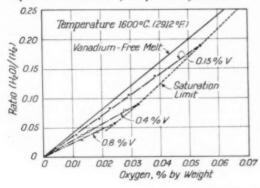


Fig. 18 (Left) — System FeO-MnO-SiO₂ at Steelmaking Temperatures. Slags or deoxidation products saturated with SiO₂ (about 50%) lie along a-b. Very fluid slags lie below a-b

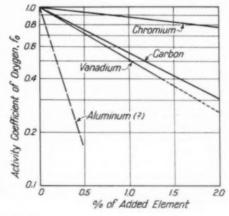
Fig. 19 — Composition of Slag and Metal in Equilibrium With SiO₂ — the Deoxidation Diagram for Manganese and Silicon Together. (Körber and Oelsen¹⁰)

power. Time was when it was thought to be a fairly good deoxidizer, and such claims could be supported by thermodynamic calculations based on the measured heat of formation of the oxide V₂O₃. But now it is being put into some grades of rimming steel, and its action there is certainly not that of a strong deoxidizer. Part of the discrepancy was removed a few years ago when the heat of formation of the oxide was redetermined, 11 and the older value shown to have been in error by some 44,000 calories! And now the whole picture is clarified by Dastur's results,*

He used the same general method that Chen had used for chromium, but with some refinements to improve the accuracy. The results were like those with chromium — only more so. For a given oxidizing power of the gas — measured by a fixed ratio (H₂O)/(H₂) — the oxygen content was increased by vanadium, as shown in Fig. 20. This means that the activity of oxygen is diminished by vanadium. Figure 21 shows the effect of vanadium on the

*Investigation sponsored by the Office of Naval Research under Contract No. N5ori-78, Task No. XVI. Recorded in thesis by Minu N. Dastur, Massachusetts Institute of Technology, 1949.

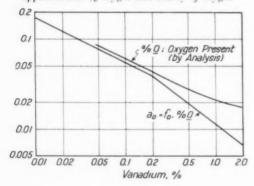
Fig. 21 — Activity Coefficient of Oxygen When Carbon, Chromium, or Vanadium Is Present With the Iron



activity coefficient of oxygen. (This is drawn on a semilogarithmic scale to make the lines nearly straight.) The corresponding lines for chromium and carbon are included, and it is observed that the effect of 0.4% vanadium is about the same as that of 2.0% chromium. It is only for these three deoxidizers that the activity coefficient of oxygen has been determined; the broken line for aluminum is a guess which will be discussed presently.

These results mean that the deoxidizing power of vanadium cannot be shown by a single line on a deoxidation diagram. As for chromium (Fig. 13) we require two lines, one for the activity of oxygen, the other for its percentage by analysis, and whether we use one line or the other must depend upon whether we wish to know how much residual oxygen is left after deoxidation, or how that residual oxygen behaves. The two lines are shown in Fig. 22. The change in slope at 0.2% vanadium is caused by the fact that above this point, the oxide phase is V_2O_3 , while at lower concentrations of vanadium, the oxide is the spinel FeO· V_2O_3 .

Fig. 22 — Vanadium in Fe-V Alloys so Reduces the Activity of Oxygen That the Effective Amount Is Shown in the Lower Line. Vertical scale applies to both % oxygen and activity of oxygen



Other Deoxidizers

For the two elements aluminum and boron, the literature contains both observed and calculated values of the deoxidation constants. In general, the agreement between calculation and measurement has been anything but good. For example, my earliest attempt¹² in 1934 to calculate the deoxidation constant for aluminum led to a value of about 10⁻¹⁴, whereas Herty¹³ found 10⁻⁸ experimentally. A few years later, Wentrup and Hieber¹⁴ published an experimental value of 10⁻¹⁰.

The basic reason for this discrepancy is now for the first time becoming apparent. The calculated value can represent only the activity, not the actual percentage of oxygen. Without experimental data on the activity coefficient, I can see no way for calculating the percentage of oxygen in aluminum-deoxidized steel at the present time. The coefficient is probably very much smaller than that for chromium or vanadium, a crude guess being represented by the broken line of Fig. 21.

The complete solution of this problem must await an experimental determination of the activity of oxygen in the presence of aluminum.

The case of boron is entirely similar. Calculations by Gurry and experiments by Derge¹⁵ have produced completely divergent results. As before, Gurry's calculations (assuming the subsidiary data are right) give the activity; Derge's measurements, the percentage.

Figure 23 contains data showing the activity and the percentage of oxygen in the presence of these two elements from the publications cited (together with others). It should be noted that the full line for each element shows the percentage of oxygen as a function of the percentage of the deoxidizing element; this is not necessarily a straight line of the slope indicated, but may be curved, as for other alloys that have been studied experimentally. The lower dashed line is the activity of oxygen plotted against the activity of the deoxidizing element (which may be quite different from its concentration). This line is theoretically straight, and has a slope corresponding to the atomic ratio of the two elements in the deoxidation product.

It is only fair to state that probably not one of the lines for aluminum or boron is correct. The one which is most nearly dependable is Derge's experimental line for boron, but the experimental difficulties were great and the results only approximate. The experimental method used by Wentrup and Hieber neglects some obvious sources of error, and their results will doubtless be revised downward. The calculated results for both aluminum and boron are based upon incomplete data, and it seems probable that when the missing parts of the picture become available, both lines will be revised upward.

The important point is that we must not expect the calculated and observed lines to coincide, for they represent two different things! In the light of what has been said, it may be predicted that they will not prove to be closer together than are the two lines representing the activity and the percentage of oxygen in the presence of vanadium.

For deoxidation with titanium, zirconium, magnesium, and calcium, there are no measurements at all on the oxygen concentration. Calculations have shown that these are all powerful deoxidizers from the standpoint of reducing the activity of oxygen.

Summary

By way of summarizing the data, Fig. 23 also presents a revised deoxidation diagram. The ordinate represents the limiting percentage of oxygen (solid lines) or its activity (broken lines) in equilibrium with the percentage of deoxidizing element shown on the abscissa. The latter is also used for the two gaseous deoxidizers, to represent the ratio of reducing to oxidizing

The lines for the gases and for carbon, chromium and vanadium are now considered to be accurately established. representing oxygen percentage in the presence of manganese, silicon, and boron are based upon careful but not necessarily conclusive experiments, and experimental confirmation or revision is desirable. The other lines will require much further experimental study before they can be regarded as anything more than rough approxima-

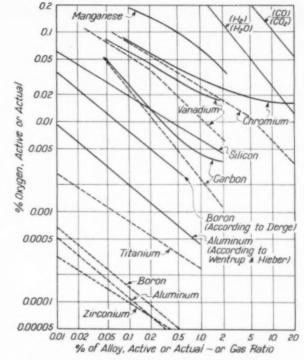


Fig. 23 — Summary of Deoxidation Equilibria. Solid lines represent percentage of residual dissolved oxygen after deoxidation; dashed lines, corresponding oxygen activity

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By H. H. Harris President, General Alloys Co. Boston, Mass.

An Approach to New Developments in Casting Control

THROUGHOUT naval history, the U. S. Navy has been one of the largest users of castings purchased from industrial foundries and the technical requirements of these castings are continually becoming more severe. To meet the present and foreseeable future needs, the Navy has sponsored extensive research and development activities in many private institutes and Naval shipyards; one of these projects was started in June 1947 at Alloy Engineering & Casting Co.'s plant in Champaign, Ill. It is my present aim to outline the fundamental considerations that have been foremost in our minds in this project, which was essentially directed toward the experimental production of intricate and highly accurate parts for high-temperature service.*

Tri-Laminar As-Cast Structures - In any approach to logical utilization of castings we must recognize the nature of the as-cast structure. This is inherently tri-laminar, in that the metal is cooled rapidly on the surface adjacent to the mold, and consequently has a fine-grain structure on the surface, encasing a progressively coarser internal structure. Ideally, it would be similar to a carburized piece with a continuous case or outer skin enveloping a core. There is an important difference: This fine outer skin of the casting is (in most forms) in compression; this stress distribution and the higher ductility of the fine grain resists notch-effect and shock, and is a dampener of vibratory movements. It has greater resistance to surface corrosion at the grain boundaries. If cast under advanced techniques, it can be far superior to a uniform structure for many engineering purposes.

Whereas a carburized bar is in effect a hard tube enclosing a tough core, a cast bar is (in effect) a tough tube enclosing a stiffer core, with an intermediate region between. This tri-laminar casting, in proper stress balance, has the merits peculiar to a laminated structure such as plywood. However, this balance must not be disturbed by later fabrication operations. Just as peeling off an outer ply from plywood would unbalance stress and create warpage, so does machining of one side of a tri-laminar casting structure contribute to warpage. The removal of the finegrain "envelope" at the surface reveals a coarser grain having less ductility, less fatigue resistance, and also more sus-

ceptibility to carbon penetration from hot combustion gases and to most corrosive attacks.

Thus, if the maximum service values are to be obtained from a casting in its as-cast condition, it should not be machined. Preferably, there should be no large-grain "break-through" areas where risers and other excrescences have been removed. This imposes the necessity of far closer casting tolerances and far better surface finishes than heretofore obtainable. Hence the molding problem was given close attention in our studies.

Mold Surfaces and Permeability — There are no scientific standards nor established methods of measuring, evaluating or controlling mold surfaces, yet means of evaluating mold surfaces (and of metal surfaces cast against them) must precede the needed controls.

Molds commonly consist of sand or similar granular materials which resist heat, bonded and separated by materials which do not. The contained air can be released from a mold (and with it the minute quantity of gas that may be contained in the metal) by small vents. A porous mold, or "permeability" as a characteristic of the mold material, is needed principally to allow the steam and the products of distillation or combustion of organic bonding materials to move away from the surfaces heated by the contact and radiation of incoming metal. Thus released, it condenses in the colder sand further from the surface, or escapes to the outside air.

^{*}A brief outline of the developments was given in The Editor's "Critical Points" last month. Mr. Harris has had general direction of the research and development described.

The need for permeability is almost proportional to the percentage of water and organic matter in the mold materials; it can be eliminated with the elimination of water and organics. Organic bond materials are generally hydroscopic and vary with atmospheric conditions. Cores presumptively "dry" generally absorb water from green sand molds. Cores and molds free from organics would be highly desirable.

To this end, "wetting", improved mold materials, particle controls, surfacing materials, bonding, and methods of dehydrating were given prime attention in this research and development.

Metal Cleanliness — Since interruptions to a smooth surface of a casting by minute foreign hodies are focal points of corrosive attack and have varied notch-effects under stress, it is important to examine the effect of cleanliness of metal in addition to the obvious desirability of a highly accurate, smooth surface, as outlined above.

The cleanliness of metal (determined by the inclusions of oxide materials, products of combustible bonding materials, oxides, slag, and gas) is of vital importance. Nondestructive testing, as available today, only partially reveals inclusions, porosities, or incipient porosities. These assume great importance in material subject to thermal shock, as the variable expansions of foreign bodies create focal points of stress and failure.

All the materials conventionally used for furnace linings, ladle linings, and molds, disintegrate under the temperature and erosion of molten metal, practically in geometrical relation to time, temperature, and pressure, each compounding the other. Maximum physical properties, fatigue resistance, corrosion resistance, or related service expectancies cannot be approached in a casting without eliminating the residue of such disintegrated refractories and the gaseous products thereof, or controlling them to a level heretofore unattained in commercial casting.

Production of metal, of unimpeachable cleanliness in the casting, was therefore another prime object of the investigation.

Internal Stresses Due to Solidification

Since it is the object of this development to make a casting of smooth surfaces and of sound, clean metal, we must also recognize that the great strength at high temperatures of the materials under study (heat resisting alloys) renders them subject to casting strains and stresses of a high order. Nevertheless, internal strains may be mitigated or controlled by modifying the form of the casting, its gating, the casting methods, pouring temperatures, heat transfer within the mold, and a complex interplay of these factors. Thus:

 Cooling and shrinkage strains in the mold are greatly influenced by heads, gates, or risers, which heretofore have received little technical consideration, yet they may strain or weaken the part in the direction of maximum load, or may add to or subtract from the thermal stresses encountered in service.

2. Heads or gates, being projections which are removed from castings, create an interruption of the final surface, and produce in that region a grain size much larger than that in surrounding areas. As fatigue life and many corrosive attacks are substantially proportional to grain size, these as-cast variations are subquality areas.

3. Castings poured quickly, in which the entire mold is filled before appreciable solidification takes place, have far greater stresses and greater internal shrinkage than castings poured in a manner to insure that much of the shrinkage of solidification is fed by incoming metal.

4. The metal that is run through a mold (as in conventional practice) into heads or risers at temperatures much higher than needed for fluidity to fill the mold, so hot that the head or riser will remain molten long enough to feed the casting, normally follows the shortest line from the gate to the heads. Local overheating of the mold in such regions delays the solidification of these hotter areas representing the path of the excess metal. These portions, after solidification, are larger in grain size and differ in physical properties from surrounding areas in the same casting. As the cooling casting is stressed, there is more elongation in the hotter and more plastic areas than in those stronger areas which cooled first.

5. Castings poured hot, out of consideration of the risers rather than the shape itself, are of inherently larger grain size than necessary. Furthermore, lacking accurate temperature control, the foundryman tends to pour hot, just to be on the safe side.

The above considerations lead to several fruitful lines of inquiry:

Pouring and Gating—The rate of pouring, and the ability to pour at a known rate, is dependent upon known and maintained dimensions of the gating system and orifice through which the metal flows. Such dimensions are seldom accurately known and almost never accurately maintained when pouring metal through sand.

Temperature Control — Temperature control is of the utmost importance. Previous to the work done on this research contract there existed no method for continuously indicating and recording the temperature of molten steel in the ladle. Without such measurement we could not provide the desired control. Without such temperature control there is no approach to a knowledge of

fluidity, and, hence, no accurate determination of flow in terms of time and weight. Neither can those physical and metallurgical variations in castings be controlled which depend upon the temperature of casting (and its related factor, the rate of solidification).

Mold Surface Temperatures - The heating of molds retards the cooling of the casting (thus creating a larger grain structure) in proportion to the temperature differential between the metal and the mold and the conductivity of the latter. While preheating of the mold is generally undesirable, it may be highly advantageous to heat molds locally in selected areas to (a) retard heat transfer to facilitate running some thin portions of a given casting, (b) keep a small gate or head hot to improve feeding, (c) delay the cooling of a given section so it may shrink dimensionally rather than internally while feeding an adjacent section, (d) offset surface-to-mass differentials and solidify all portions simultaneously or in correct sequence, and (e) balance, in a given mold. the excess temperature in some other portion resulting from an "unavoidable" head or gate.

Control of Properties—The reader will see that the aim of this Navy contract is to develop methods that will enable accurate castings to be made, sound and clean in structure, having uniform grain size characteristics throughout (a) the surface and (b) the core, and free from internal strains caused by thermal differentials and uncontrolled solidification rates. It may be thought that too much emphasis is placed on grain size. Ample experience shows that this is not true for the high alloys used for high-temperature service.

As the section is reduced, as-cast sections in most metals and alloys have increasing ductility and elongation figures and bend test angles. A ½-in, section may have more than twice the elongation of a ½-in, section cast from the same ladle. Where a 1-in, section of an as-cast nickel-chromium alloy had 12% elongation, a ½-in, section of the same casting had 38% elongation! This difference in ductility arises from grain size differentials inherent in the surface-to-mass ratios and the different cooling rates of the different sections. It, therefore, becomes obvious that

 The "standard" data more or less applicable to heat treated and rolled products have little or no relation to as-cast sections.

Physicals determined from conventionally cast test bars, "standard" bars machined from thick sections, or "precision-cast to size with threads under tension" also bear a very indefinite relation to any other form or section poured at any other temperature.

The basic structure is often far more important than variations in analysis—sometimes, even, than the material selected. A "brittle" material can be ductile in thin sections while a "ductile" material can be brittle in thick sections. This is particularly true of thick sections poured at high temperature and having a large grain size.

In many of the heat and corrosion resistant alloys in as-cast form, there is a difference of 3 to 1 in degrees of bend-test in two specimens of the same size and section poured at different temperatures from the same ladle—the lowest temperature producing far superior test results. (In conventional practice, molds are poured in sequence at greatly varying temperatures.)

Therefore, the physical properties of a given part will vary greatly with varying sections, and thus contribute extensively to the distribution of residual stress. In thin, as-cast sections many "hard" materials become relatively "soft". Changes in analysis to obtain maximum physical properties may open a new metallurgical approach to castings' improvement.

The problem of balancing these opposing factors to produce a casting of optimum properties was a most important aspect of the research.

Adequate Design — To those working closely with the interrelation of (a) forces encountered in service, (b) design-form requirements, (c) metallurgy and (d) casting techniques, it becomes apparent that formal education and usual industrial experience do not provide the scope and specialization necessary for the logical evolution of service design and production of heat-resistant alloy castings for severe stresses. It is hoped that this Navy project will help lay the foundation for the understanding of the as-cast materials and their tri-laminar structure, requisite to American leadership in gas turbines and other high-temperature mechanisms.

Economics—It is anticipated that casting research and development, such as the Navy's project at Champaign, will result in lighter, stronger and more serviceable castings at a lower cost in ratio to their service performance—also to produce them when the need arises. Some economic considerations are:

.1. Increasing yield (the percentage of usable castings per pound of metal poured) holds great economic advantage. A 40% reduction in the gating and heading, or the unusable metal poured, would produce the same usable castings from four heats as are now produced in five heats.

Improved cleanliness and substantial economies in floor space, in materials handled, in cleaning, machining, and in scrap, should result from the envisioned improvements in practice.

 Broader application of improved eastings for defense may well broaden the civilian markets, to the general economic benefit.

A New Method

for Surface

Reproduction

IT HAS BEEN KNOWN for many years that photographic emulsions are sensitive to mechanical pressure. When a photographic emulsion is placed between surfaces and a pressure applied perpendicularly to the emulsion, a latent image is formed. The film or plate is then developed by conventional procedure. The phenomenon has hitherto been regarded as a scientific curiosity and has received neither explanation nor application, although a discussion of the physical nature of the "photographic pressure effect" was printed in the Journal of the Optical Society of America in 1948 (Vol. 38, p. 1054). It now seems that it can be explained better as a temperature effect, the temperature resulting from heat generated by compression of the emulsion in the case of static pressure, and by friction when sliding occurs,

In some work at Washington University (stimulated by other projects in the physics department supported by grants from the Office of Naval Research) we investigated the possibility of using the pressure effect to form three-dimensional images of surface finishes. Our equipment is sketched in Fig. 1. The specimen surface is prepared in the form of a thin disk of the same diameter as the flat face of ball A (¼ in.). The photographic plate P is placed emulsion side up between the prepared surface of specimen S and the flat surface of ball A. The mechanical arrangement is designed to insure

proper seating of the specimen's surface on the emulsion. Ball A rotates fairly freely in the grease-packed well W, allowing it to square the specimen against the emulsion. A hydraulic press is applied to plunger D, the pressure applied to a specimen being indicated by a gage.

The apparatus could apply pressures as high as 120 tons per sq.in., although much lower pressures than this were generally used. Glass photographic plates would break at about 25 tons per sq.in. In general, pressures of the order of one-quarter that much (1000 kg. per sq.cm., or 14,000 psi.) have proved adequate for reproducing metallic

surfaces, but probably there is an optimum pressure for a particular kind of surface. For instance, the rougher the surface the greater the pressure required to insure intimate contact over the whole.

Pressures were usually applied to the emulsions for about one minute. However, this is more or less a matter of convenience as the ultimate density (opacity) produced in the developed emul-

If a reasonably flat metal surface is pressed into a fine-grained photographic emulsion at about 15,000 psi., and the plate developed and examined under a microscope, a pattern will be found that reproduces the surface contours. A pronounced three-dimensional appearance results, since the high portions of the surface are responsible for denser regions in the developed emulsion. If standardized, the method might give a quantitative measure of surface roughness.

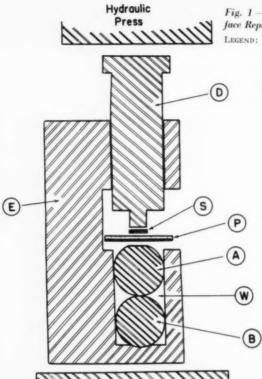


Fig. 1 — Equipment for Impressing Surface Replicas Into Photographic Emulsions

LEGEND: A - %-in. steel ball with 14-in. flat ground on.

B - Free-turning %-in. steel ball.

D - Plunger.

E - Supporting frame.

P - Photographic film or plate, emulsion up.

S - Specimen under study, prepared face down.

W - Grease-filled well.

unprotected emulsions. The Ilford "Nuclear Research Plates B2, C2, E1 and D1" and Eastman "Nuclear Track Plates A, B and C" seem to be very sensitive to pressure. Furthermore, these emulsions are much thicker than regular types—for example, they are available from 50 to 200µ thick, and the thicker the emulsion the better it is able to "accommodate" a rough surface pressed into it. The high spots of the surface presumably sink into the emulsion, permitting intimate contact over a wider area of surface than if the emulsion were thinner.

It should be noted that in this process the photographic plates are not exposed to light at any time until after they are developed. The latent image results solely from the operation of compressing the emulsion. The hydraulic press is set up in a photographic darkroom and the entire operation carried through under a safe light. (The Ilford nuclear research plates are not very sensitive to light, permitting a fairly yellow illumination to be used in the darkroom.)

The pressure negatives, when developed, must be examined with a microscope at appropriate magnification. The emulsions referred to possess a fine grain size, not exceeding 0.5μ after development, and therefore allow a high resolution. For example, the negative from a test grating ruled at 400 lines per millimeter was distinctly resolved on an Hford C2 plate. Magnifications as high as 1000 diameters can sometimes be used profitably. In the event the technique finds engineering applications, the resolution could probably be improved by using extra fine-grain emulsions of the Lippmann type.

Applications to Studies of Surfaces

The particular feature of the technique which makes it well suited for surface replicas is its fidelity in reproducing the third dimension of a contour. A gelatin emulsion, even in the dry state, is sufficiently plastic that under pressure it assumes the shape of the surface on which it is pressed. In particular, the greater the pressure at any point on the emulsion the greater the density at that point after development. Hence, high

sion is independent of the duration. The density does depend on the rate at which pressure is applied; it is greater if the pressure is applied rapidly. (Considering the mechanism of latent image formation as a temperature effect, rapidly compressing the emulsion corresponds more nearly to adiabatic conditions and results in a greater rise in temperature.)

After compression, the photographic plates were developed, fixed, washed and dried in the conventional fashion. Choice of developer is not important although the contrast in the "pressure negative" depends on the choice of developer and developing conditions (as is true of plates exposed to light).

The type of photographic emulsion is important. It should be emphasized that most regular photographic emulsions do not display any pressure sensitivity, due to an inactive surface coating of gelatin about 1µ thick intended to protect the emulsion from abrasions which are subsequently developed. For pressure work of the kind described here it is therefore necessary to secure

spots on a specimen surface cause greater-thanaverage density while indentations cause lesser density. The three-dimensional nature of the specimen surface is thereby made evident by gradations in density across the negative. The result is a high-contrast, transparent replica* of the specimen surface.

The chief advantage of these replicas is their combination of high contrast with transparency. Direct bright-field illumination may be used in the microscopic study of opaque surfaces, if the investigator first prepares replicas in the above manner. In addition, the pressure negatives serve as permanent records of the surfaces copied. The photomicrograms reproduced here were made from replicas in the manner described.

itself, has been noticed. Emulsions frequently are not quite flat but themselves possess high spots which appear as black spots on the pressure negatives, indistinguishable from the effect of true

One difficulty, introduced by the emulsion

high spots on the specimen surface. (These can be clearly seen in Fig. 3.) Another difficulty concerns a tendency for the plates to slide when under compression unless the pressure is applied exactly perpendicular to the emulsion's surface. Any movement results in spurious scratch marks which conceal the proper structure of the surface being studied. However, the chief restriction of the method is the necessity for using high pressures to reproduce surfaces; it is limited to specimens that can tolerate pressures approaching 15,000 psi. - a restriction, it must be noted, that applies principally to nonmetallic materials.

A promising application of this technique is therefore to the study of metals, and it is equally practicable to reproduce the detailed structure of any kind of surface - machined, lapped, or polished, the structure of fractures and fibrous materials. By a reasonable improvement in resolution it may be possible to record grain boundaries on polished or etched metal. Although photographic replicas are intended to be complementary to existing techniques, they naturally suggest themselves, because of their inherently high contrast, for the same problems to which metallography is applicable.

*Editor's Footnote - The word "replica" is to be interpreted as "optical re-creation" and not (as is now the usual meaning of the word) as a threedimensional exact model, capable of being used in electron-diffraction studies,

End-Turned Steel Cylinder

Steel Finished on Surface Grinder



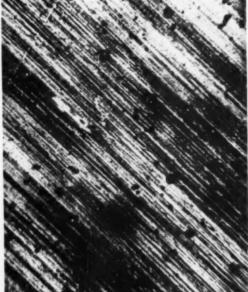


Fig. 2 and 3 — Reproductions Made With Ilford E1 Emulsions, 14,250-Psi. Pressure, Magnified 100 Diameters

Correspondence

French Metallurgists in Resistance

PARIS. FRANCE

To the Readers of METAL PROGRESS:

I was very sorry when I read in last December's issue of Metal Progress Mr. Corson's pronouncement against the conduct of French metallurgists during the years 1942 to 1945 of the German occupation. In his judgment the work published in Revue de Métallurgie for 1944 was "much deeper and carried more precision than the work done before", and therefore he concluded that the Germans must have encouraged such substantial scientific work. His judgment is a very stern one, and his conclusion completely false. I am therefore hopeful that many Americans will read this letter as well, so that the truth may be re-established in their minds.

Since your reviewer gave some space to my own work on toughness, published in that issue of *Revue de Métallurgie*, perhaps it is in order to say a few words about it before passing to more general and important considerations. My contribution gave only a theoretical discussion, the result not of tests but of debates with my French colleagues. The practical results of my conclusions were indeed not yet developed and were not published until October 1947. It is hard to see how this could have "benefited the common enemy", as charged by your reviewer.

It will probably be of more interest to American metallurgical friends if I say something of the wartime activities of the Renault Automobile Works, and more particularly of the Works Laboratories, of which I am the head.

It must be admitted that the directors of the works were faced with a painful decision, immediately Paris was taken by the enemy. First, large working forces (and their families) were dependent upon operation for their daily bread. Second, active resistance would have been an invitation for the severest reprisals—even to innocent relatives. Third, if the Germans themselves had operated the plant, much more effective war matériel could have been manufactured.

How effective passive resistance can be may be judged from the following facts: Prior to occupation we were making tanks, large aircraft engines, and fighter aircraft for the French forces. Not one tank was produced during the four years of German occupation. We took a year to reconvert for the manufacture of light trucks, training planes and engines - all to German designs. Special equipment was always late! At preoccupation rates, Renault should have produced 9000 heavy aircraft engines in the three years of occupation: actually 300 engines for training planes were shipped! With 25,000 workers, the Renault plant produced 20 German trucks per day, a favorable comparison with 150 cars and 100 trucks per day prewar, and 450 cars today.

Every argument was used to explain the delays: New steels; revisions in parts requiring long test programs; delays in getting test equipment; extensive retests under the slightest pretext; slow delivery of machine tools; steel shortages; heavy rejects for various defects (genuine or not).

This tacitly organized sabotage was continued during the whole occupation. As a matter of fact, we were aided in our designs by the bombardment of our plants (which unhappily killed some bundreds of civilians in the neighborhood).

So much for the plants generally. How about the Works Laboratories, which were in my charge?

We first separated the research and the plant laboratories. The research laboratory operated so secretly that no single German set foot in it during the whole war. The laboratories for testing incoming materials and parts in process, tests on subassemblies and completed machines, as well as for the solution of manufacturing difficulties, were open to German inspectors. As far as they knew, all research and development on war equipment had stopped in 1940. Our testing laboratory became adept at labeling the best steel heats "bad", and the bad ones "good". Our steelplant was a master in the art of making ball-bearing steels full of flakes and inclusions!

As a special precaution against accidental discovery, our secret research laboratory near Paris was occupied with projects that related to peacetime developments of promise. Some researches of direct application to ordnance were performed in our steel plant at St. Michel de Maurienne, in the Free Zone, and these also remained unknown to the Germans.

I apologize for writing at such length and of my particular case alone. I do so only because I believe it is representative of all the French metallurgical fraternity.

JACQUES POMEY Chief of Works Laboratories Renault Automobile Works

How the base metal protects the finish



t is almost always the case, though unsuspected by the general public, that the material to which a finish is applied has a definite influence upon the perfection and durability of that finish. For example, products that are nickel or chromium plated stand up better if the base metal is nonrusting, as is copper and brass. To take another example, look at vitreousenameled emblems, used as trademarks, name plates, medals, lapel pins, insignia, and so on. Most of these emblems have a copper alloy as the base metal; only that, or gold or silver, can be used.

These emblems owe their beautiful

and permanent colors to silicate pastes and powders, inlaid by skilled artisans. and twice fused in a furnace at a temperature of about 1500° F. This temperature sets high standards for the underlying metal which must not warp, nor "bubble up" into the enamel. Thus visible beauty for which so much creative skill is required, depends in part on the invisible metal underneath. Revere, which takes great pains to maintain the strict standards of its alloys, is proud to meet the high requirements of American Emblem and other companies in this field . . . Perhaps Revere can help you by supplying exactly what you require to protect the finish and durability of your

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August, 1949: Page 229

Personals

Harley S. Van Vleet , formerly chief of the container research of American Can Co. at Maywood, Ill., has been appointed manager of the Atlantic Division research of the company, with headquarters in New York City.

Henry P. Nielsen , who graduated from Cornell University in June 1949, is now employed by Procter & Gamble Mfg. Co. at Port Ivory, Staten Island. N. Y.

Atlas Steels, Ltd., Welland, Canada, announce that Gilbert Soler , who joined the company in 1946 as works manager, has been promoted to vice-president for manufacturing operations and a member of the board of directors. E. P. Geary , who joined the company in 1947 as vice-president and general sales manager, has also been appointed to the board of directors.

C. W. Barnthouse (2) has been appointed California district manager for the Latrobe Electric Steel Co., his headquarters being in Huntington Park, Calif.

Adolph O. Schaefer (3), assistant to the executive vice-president of the Midwale Co., Philadelphia, has been appointed to the research committee of the Franklin Institute of that city.

Fritz V. Lenel \$\mathbf{\omega}\$ and Arthur A. Burr \$\mathbf{\omega}\$ have been appointed associate professors in the department of metallurgical engineering at Rensselaer Polytechnic Institute, Troy, N. Y., and Ralph R. Nash \$\mathbf{\omega}\$ has been named assistant professor. The three men have been with the department since 1946.

Great Lakes Steel Corp., Ecorse, Mich., announces that Hubert C. Smith has been appointed assistant vice-president in charge of metallurgical control. Mr. Smith, who was formerly chief metallurgist, came to Great Lakes Steel in 1936 from the Otis Steel Co.

Carl A. Zapffe and M. E. Haslem have been awarded a certificate of honorable mention for their paper presented to the ferrous division of the Wire Association in Pittsburgh in October 1948.

Correction: We wish to correct a statement in the June 1949 issue of Metal Progress, page 854, to the effect that A. W. Mace "has established a consulting service". Mr. Mace is consultant for steel requirements for the armed forces, on the staff of the Office of Industry Cooperation, Department of Commerce, but has not established a consulting service.

Harley A. Wilhelm (2), assistant director of the Iowa State College Institute for Atomic Research, was awarded the Alumni Merit Award by the Iowa State College Club of Chicago for "meritorious service in his field and contributions to his fellowmen".

W. A. Wesley , W. W. Sellers and E. J. Roehl have been awarded the 1949 Founders Gold Medal of the American Electroplaters Society for their technical paper, "Electrodeposition of Nickel at High Current Density". Mr. Wesley and Mr. Sellers are at the Bayonne research laboratory of the International Nickel Co., Inc., and Mr. Roehl is with the Thomas Steel Co. of Warren, Ohio, but was formerly with the Bayonne research laboratory.

Thomas F. O'Brien , formerly head of the industrial chemicals division of Waverly Petroleum Products Co., has been appointed to head a similar department at MacDermid, Inc., Watertown, Conn., following the purchase of Waverly Petroleum by MacDermid.



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high carbon high chromium steel tools or dies at low

production cost even with inexperienced help. For

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WE SAY IT WITH FLOWERS

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GENERAL ALLOYS COMPANY should not be confused with "foundries", for the foundry is only one of the tools of this National Engineering Organization.

ONE of many examples where General Alloys has unequalled experience and proven service records is in rails for industrial furnaces. Back in 1935 General Alloys, working with M.I.T. and others, tested thirty rail designs. Some are shown on the right. The rails in the bottom group have half the weight of most of the rails in the top group, do the same work. Better design, metallurgy and accurate wearing surfaces make this possible. Which ones are yours?

NOW that operating economics attract intensified management analysis, life records of heat treat tooling and furnace parts are being kept, as before the war, and the facts of service life in functional utility and cost-per-heat-hour tend to govern purchases.

MANY thanks,— and again we SAY IT WITH FLOWERS to a top executive of a large automotive producer who, in a memorandum to his purchasing department, stated in part:

"NOW, WE CANNOT AFFORD THE HIGH ACTUAL COST OF 'CHEAP' ALLOYS"

-H. H. HARRIS



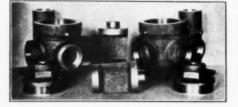
DIFFICULT and unusual casting problems, particularly the ones that others have failed on or that "can't be made", are welcomed by G. A. The same engineering experience and process control that makes the "tough" jobs also does a better job on the simple ones too.

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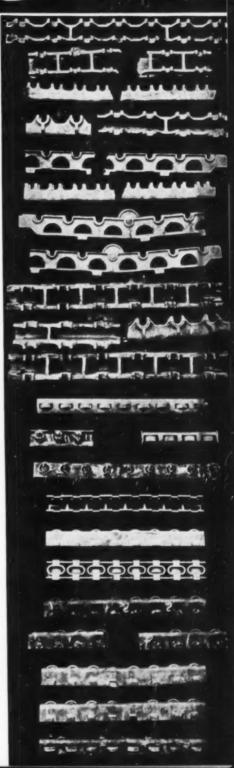
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Personals

R. A. Quadt (a), formerly assistant manager of the general aluminum department of Federated Metals Division, American Smelting and Refining Co., has been appointed manager and his headquarters moved from Detroit to New York City.

Donald Bryden (3), associated with the Philadelphia Branze and Brass Corp. for 22 years, has been elected president and director of the firm.

Central Iron and Steel Co. announces that William F. Zerbe has been appointed to the newly created post of vice-president in charge of operations. Mr. Zerbe has been associated with the company for 38 years.

L. E. Snellgrove is now vicepresident of Elmer Pfeil, Inc., Cleveland, distributors of new and used equipment. J. E. Corbett , formerly with the Akron Standard Mold Co., will now do development and sales work for Alcon Products, Akron, Ohio.

Jay W. Fredrickson (a), formerly with the University of Utah, has joined the staff of the school of mineral industries, Pennsylvania State College, as chief of the division of metallurgy.

Norman W. Nielsen has accepted a position as metallographer at the Davenport, Iowa, rolling mill of the Aluminum Co. of America.

Following graduation from the University of Minnesota with a Ph.D. degree, John W. Axelson has accepted a position as research engineer in the research center of Johns-Manville Corp., Manville, N.J.

Robert C. Lindsay (a), formerly in the metallurgical products section of the General Electric Co., Schenectady, is now with the Utica Drop Forge & Tool Corp., Utica, N.Y., as a customer contact engineer in the precision forging division.

Erwin B. Bahnsen 🖨, formerly chief engineer with the Victor Mfg. & Gasket Co., has established Steel-Cor Mfg. Co., Inc., Chicago, a partnership, engaged in the production of packing materials.

M. K. Yen is now working as a research associate in the research division of the college of engineering, New York University, New York City.

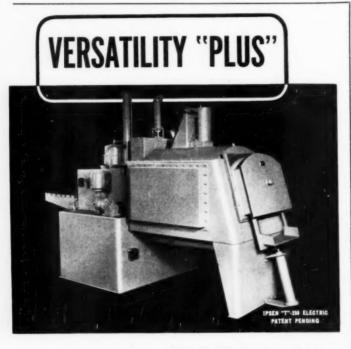
John A. Franck , who recently graduated from Ohio State University, has accepted a position as student corrosion engineer with the International Nickel Co. at Kure Beach. N. C.

John F. Crane, newly elected chairman of San Diego Chapter, American Society for Metals, has accepted a post as chief engineer of Rocheville Engineering, Inc. He was formerly in the engineering section of Ryan Aeronautical Co.

Robert C. LeMay \$\ \text{has recently joined the sales promotion department of the Selas Corp of America in Philadelphia.}

Maumee Malleable Castings Co. announces the promotion of N. P. Mahoney & to the post of plant manager. He joined the firm in 1920 and has served as purchasing agent, production manager and superintendent.

W. R. Toeplitz has been elected to the board of directors of Bound Brook Oil-Less Bearing Co., Bound Brook, N. J.



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annealing and hardening of both large and small parts are accurately performed by these flexible Series "T" Units. Standard models consist of a furnace (gas or electric), a water-jacketed cooling chamber, and an enclosed quench tank—all under controlled atmospherel

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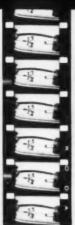
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Metal Progress: Page 232

Write for Bulletin "T".



It can show you the heartbeat of a car radio -



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<u>High Speed</u>

Camera

You could cover pages with calculations about a car radio vibrator. You could fill sheets with figures on inertia and elasticity of its vibrating elements—and yet not be sure exactly how the rapidly moving parts do behave in action.

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Addition of Steam to Blast Furnace*

OF THE FACTORS that might be varied to increase the speed of reduction in the blast furnace, improvements in the physical condition and chemical composition of the ore have already been made, and the temperature of the surroundings is fixed in a given furnace. However, there are enormous possibilities in changing the composition or pressure of the gaseous reduction agent.

Increasing the gas pressure on any heterogeneous reaction significantly increases its velocity, and in a blast furnace higher pressure causes diffusion of gases inside pieces of ore, thus further speeding the reaction. Although present large blast furnaces use somewhat higher pressures than the older, smaller ones and therefore operate better, attempts to use valves at the top of the furnace to greatly raise the gas pressure have not been successful. Future blast furnaces may be small and solidly built to withstand ten atmospheres or so of gas pressure.

Changing the gas composition and permitting the successful use of a catalyst may be more useful ways to increase the reduction velocity. In choosing a catalyst there must be considered the feasibility of obtaining it industrially. and the ease and economic expedience of applying it under blast furnace conditions. Hydrogen is the best known catalyst and causes such a reduction reaction as

FeO + C = Fe + CO

to go with greater speed in its presence by means of the reactions

FeO+Ho=Fe+HoO $H_2O + C = H_2 + CO$

The catalytic hydrogen is recovered.† The difference in the reducing action of CO and H2 is explained by: (a) the difference in stability of their oxides - below 840° C. H₂O dissociates more easily, (b) the faster diffusion of H2, which makes its reaction rate four times that of CO, (c) the reduction of H2O in preference to iron oxides at all (Continued on p. 236)

*Abstracted from "Catalysts for *Abstracted from "Catalysts for the Reduction Process in Blast Furnaces", by M. I. Korobova and N. I. Korobov, Izvestiya Akademii Nauk S.S.S.R., Otdelenie Tekhnicheskikh Nauk, 1946, p. 567-577. (In Russian.) †Editor's Note: The action of hydrogen in increasing the over-all rate of reduction is not "catalytic", in the common sense of the word.

in the common sense of the word.

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Blast Furnace

(Continued from p. 234) temperatures by C and CO, and (d) the special activity of nascent hydrogen.

Catalytic gases other than H., are unknown, while cost and scarcity prevent the use of solids such as Ni. Co. Pt. Hg. Cu and V. Carbon in one of its active forms is a suitable catalyst, and carbon-black forming inside pieces of ore shatters them. thus increasing the reaction surface. Preliminary tests have shown that from 5 to 8% Na₂O in the charge increases the reduction velocity of titaniferous ores by two to ten fold.

Although 96% H., can be produced commercially for direct introduction with the blast into the furnace, the process is complex and costly. Therefore the procedure used was to add steam to the blast and to allow H₂ to be produced inside the furnace by the reaction of the H₀O with CO or C. This was first done in Russia in September and October 1939, by L. Ya. Gabrielyan. After five days of normal operation in which comparison data were obtained, gradually about 5% steam was added to the blast with additional heating of the blast to compensate for the heat lost in decomposing the steam.

Over a 23-day program the quantity of steam added to the blast was from 1.5 to 4.0 tons per hr., the blast temperature was between 750 and 800° C., the blast volume was between 2400 and 2600 cu.m. per min., and the average daily tonnage was 1455 compared with 1135 for ordinary operation. The ${\rm H_2}$ content of the blast furnace gas was 4.4% instead of the usual 1.5 to 2.0%. The oxidizing zone in the furnace was widened considerably because of the decomposition of the steam. The furnace ran more evenly and coke consumption per ton of iron decreased.* An 11-day run in a second plant confirmed these results.

It is concluded that the steamair mixture can be used to avoid a number of operating difficulties, as well as to increase the productivity of the blast furnace. The mixture is mandatory for all furnaces, but the amount of steam is limited by the permissible blast temperature - 6% H₂O is the limit for a blast temperature of 1000° C.

*EDITOR'S NOTE: During the war, steam was added to some American blast furnaces as a corrective measure when the quality of the coke was poor. However, American experience was that an increased amount of coke was required.

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Testing of Bearing Materials*

THE tests previously used for bearing materials were of the service type and were unsatisfactory because they took a long time and failed to separate the variables influencing bearing life. This paper describes several test methods and machines developed in Russia to determine the essential requirements of a bearing material.

To test the ability of a bearing material to "run in", the periphery of a rotating hardened steel disk is caused to rub against a block of the test material by means of a load. q, thus causing a depression to be worn in the material. The depth of the depression increases rapidly at first but approaches a constant value in a short time. If the load is increased to 2q the depth again increases and approaches a higher constant value. If from results of this kind a plot of depth versus unit pressure on the bearing metal is made, a limiting value of pressure, p_{max}, is found following a period of constant increase. As criteria of the ability of a given bearing metal to "run in" both the value of $p_{\rm max}$ and the slope of the curve of constant increase of p are used.

Of the various types of wear that occur in bearings, abrasive wear is of most interest. In 1937 two new principles of abrasive wear testing were announced: (a) rubbing must always be on a fresh abrading surface, and (b) the abrasion capacity of the abrading surface must be quantitatively determined by means of a standard material. These principles were incorporated in a test in which one end of a directlyloaded cylindrical bearing-metal specimen was rubbed against a horizontal rotating emery-cloth disk. By gradually moving the specimen radially, fresh abrasive material was continuously made available. Only half of a given emery disk was used in testing one bearing metal; the other half was used to rate the abrading capacity of the emery by means of a standard material. The measure of wear is the decrease in length of the test material compared with the decrease in length of the standard. For homogeneous (To p. 239)

*Abstracted from "New Methods of Testing Bearing Materials", by M. M. Khrushchov, Izvestiya Akademii Nauk S.S.S.R., Otdelenie Tekhnicheskikh Nauk, 1948, p. 1613-1620. (In Russian.)

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Bearing Materials

(From p. 238) alloys and pure metals there is an inverse relation between wear and macrohardness. This law does not hold for heterogeneous alloys.

The value of microhardness testing of bearing materials is shown by the following examples. The ability of bearing metals to absorb abrasive particles is higher the lower the hardness of the softest constituent in the cold worked surface layer. Also, if scratching of the steel shaft is to be avoided, the shaft hardness must be greater than that of the hardest component of the bearing.

Fatigue failures leading to the formation of cracks and the crumbling of the bearing layer are a serious problem in bearing design. Two methods are available for the fatigue testing of steel-backed bearings. The first consists in vibrating the end of a cantilever beam of the bimetallic specimen until the first crack in the polished surface can be seen with a hand lens. The results are plotted as the logarithm of the amplitude of vibration versus the logarithm of the cycles needed to crack. The second method consists in rotating a steel ring, with the bearing metal cast inside, under the action of three rolls that exert pressure on the ring. Again the results are plotted as the logarithm of stress versus the logarithm of cycles to first appearance of a crack. Dynamic rather than static values of the elastic moduli are needed for stress calculations, and these are determined by special methods on the steel-backed bearing metals.

Although sketches and descriptions of the testing machines are given in this article, no test data are listed. However, these are undoubtedly given in most of the nine Russian papers cited as references.

Safe Techniques With Tracers*

USE of radioactive tracers has introduced entirely new risks in handling otherwise innocuous material. Exposure to external radiation or introduction of radioactive substances into the body through inhalation, (To p. 240)

*Extracts from "Watch That Spill", Industrial Bulletin of Arthur D. Little, Inc., July 1949.

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Tracer Elements

(From p. 239) by mouth, or absorption by the skin constitutes a health hazard, even when the quantities involved are extremely small. Cross-contamination of experiments by transfer of radioactivity from one area of the laboratory to another is considerably more difficult to avoid.

The design of the individual laboratory and the experimental procedures vary according to the quantity and type of radioactive material. Substances emitting "hard" radiations, even when enclosed in glass, must be surrounded by lead or concrete, and the worker must employ long tongs and similar instruments. (Editor's Note: These would not appear in any metallurgical work that has yet been publicized.) "Soft" or low-level radiation is stopped by rubber gloves, a few inches of air space, or other light barriers. These materials are dangerous, however, within the human body, and must not contaminate other experiments.

There are at least two approaches to handling material with low-level radiation. One involves complete confinement of the material within scaled equipment. A number of operations requiring several days may be carried on inside trains of containers, with the solutions moved from flask to flask by syringes. The same principle is applied with the "dry box", a metal' or wooden box equipped with windows and two large rubber gloves sealed into the wall of the box, for manually manipulating equipment inside the box. With the radioactivity so confined, the remainder of the laboratory can be constructed along conventional lines.

In the second, and more common, approach, modifications of normal laboratory procedure are used. Possibility of contaminating the laboratory is recognized and periodically checked. Provision is made for more ventilation, with a fairly high face velocity through openings in hoods, boxes, and other working areas, and frequent changes of air throughout the laboratory. Permanent equipment and structures are designed for easy decontamination - which may range from simple scrubbing to complete removal and disposal of the contaminated surface.

Protective Coatings - Plastic films which can be peeled off easily have been found useful as a pri-(Continued on p. 242)







Ajax Induction Holding Furnace at Mid Western Die Casting Co.
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Metal Progress; Page 242

Tracer Elements

(Starts on p. 239) mary barrier to protect permanent coatings and base materials from radioactivity. These films may be adhesive-backed plastic sheeting, or a clear coating sprayed on, like paint. Paint which has become contaminated is softened with paint remover and scraped off. Where radioactive products have penetrated base materials, they may be ground or scraped, or it may be necessary to remove them for disposal. Use of base materials which are absorptive, which create dust when scraped, or are difficult to remove, is avoided. Concrete floors. for example, are preferably protected with renewable flooring material. In the ideal laboratory, the interior walls would be made of double, painted, metal panels, individually removable without dis-

All surfaces should be made as smooth as possible and cracks covered or filled with caulking materials. Laboratory furniture (benches, hoods, and sinks) in the newer laboratories are being made as easily removable as possible and at the same time are protected with paint and films to minimize the necessity for replacement. Bench tops, for example, are coated with plastic sheeting and then covered with stainless steel trays to confine any accidental spill or spatter.

turbing the adjacent laboratory.

Some of these newer desirable features can be economically achieved only in newly designed and constructed laboratories. Fortunately, the more important requirements for low-level radiation may be adequately met by superimposing suitable materials and methods on the existing buildings and equipment.

Effects of Internal Stresses

I N previous issues of Metal Progress, the first 30 papers in the "Symposium on Internal Stresses in Metals and Alloys" (Institute of Metals, London, 1948) have been reviewed. The last section of the Symposium, consisting of six papers on effects associated with internal stresses on a macroscopic scale, is considered here.

This section begins with a paper (Continued on p. 243)

Internal Stresses

(Starts on p. 242)

hy U. R. Evans, the well-known specialist on corrosion phenomena. His paper is one of the longest in the monograph (26 pages, 73 references) and begins with a brief description of his experimental work with stresses in oxide films on nickel, for which he developed a method of transferring the films to a coat of vaseline on glass. The film is under a state of stress while on the metal and, on release, it wrinkles, rolls up or develops gaps according to the stress and film thickness at the given point.

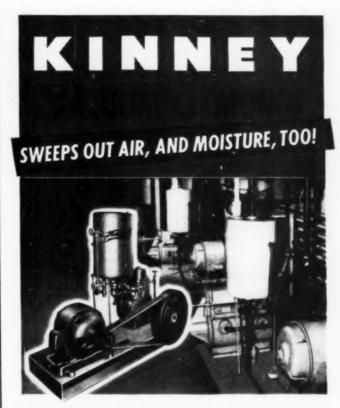
In the third subdivision of his paper, Evans discusses briefly the theories of oxidation in general and even more briefly the theory of finite thickness of the oxide film on aluminum. As to the influence of internal stresses existing in the metal itself, he says that these will presumably be inherited by the film of oxide and add to its own stresses.

The author discusses next the effect of residual stresses on three types of corrosion in liquid mediums, namely, anodic, by dissolved oxygen, and by acids. This is followed by a discussion of stresscorrosion cracking of brass, aluminum-magnesium alloys, aluminumcopper alloys, caustic cracking, nitrate cracking, gas-detarrer cracking, and corrosion fatigue. The latter is given only ten lines; it requires applied stress, but residual stresses are used as correctives. Finally the author examines the mechanical, thermal and zinc coating treatments as remedies against stress corrosion.

Although this paper is almost the longest of all published in the monograph, the scope treated is so large that the treatment becomes rather sketchy.

The reader can get more specific information from the article by F. H. Keating on the chemical manifestations of internal stress (23 pages, 98 references). His brief introduction represents a precise statement of the stress-corrosion phenomena, and it is good to read that despite the many studies of stress corrosion in aluminum allovs and stainless steels, which might lead to the false idea that the problem is quite acute, "the service performance of the alloys appears to be very good from the point of view of stress corrosion".

This clear-cut introduction is followed by the discussion of specific items arranged by the basic (Continued on p. 244)



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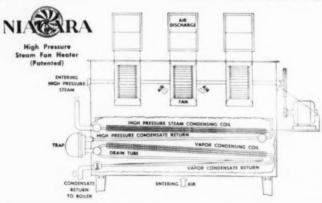
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Internal Stresses

(Starts on p. 242)
metal in the alloys in question. First come the brasses and tin bronzes; it is stated quite definitely that the season cracking of these alloys is caused by the release of tension stresses by the corroding medium and that pressure stresses produce no season cracking. Another important statement tells us that the action of mercury is not yet understood and that the action of that element and the action of ammonia are by no means identical.

Talking about light alloys in general, the author points out that the numerous laboratory investigations had no background of urgent industrial demand, for the number of stress-corrosion failures of light metal parts in service, as reported in the three nations intensely and actively interested, has been very small. The research work done was essentially of a scientific nature leading to an increase in understanding — not to immediate results.

Next Keating examines the aluminum alloys containing precipitates of CuAl₂ or Al₃Mg₂, where the action of stress accelerates the rate of corrosion if a state of advanced grain-boundary precipitation exists. The magnesium alloy containing 1.5% Mn is fairly resistant to stress corrosion, but the alloy containing 6% Al and 1% Zn is rather sensitive in this respect. The few service failures known have been attributed to residual stresses from fabricating operations, not to service stresses.

There follows a brief statement that cracking of highly stressed nickel has been observed in fused caustic soda and caustic potash and that stress relieving between 550 and 850° C. has been found effective in climinating cracking. Lead can fail by intercrystalline cracking if stressed in tension in the range of 170 to 570 psi.

Turning to ferrous materials, the author discusses caustic embrittlement and the cracking of mild steel in nitrate solutions. The treatment of the subject is too brief and too thorough to permit abstracting, for almost every word of it is of distinct importance.

Coming to the austenitic stainless steels, the author discusses the intergranular corrosion due to carbide precipitation, in which the service stress or the internal stress can be of a merely auxiliary nature, and where no stress relief by low temperature treatment can be of

(Continued on p. 250)

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Metal Progress; Page 246

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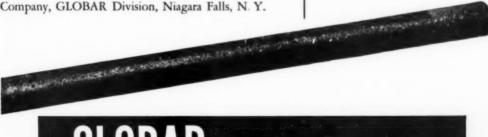
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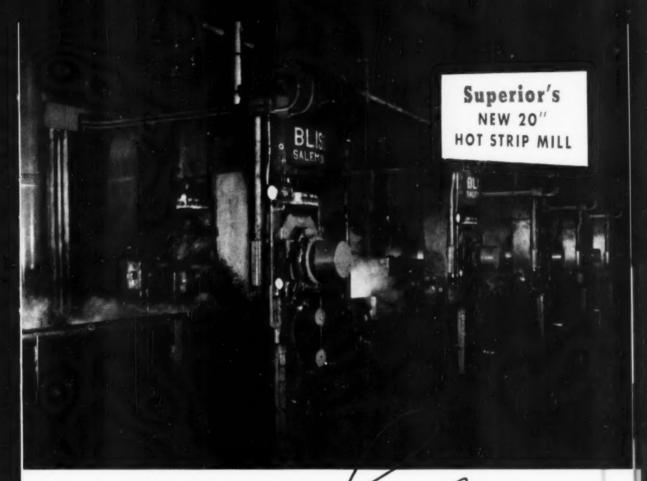
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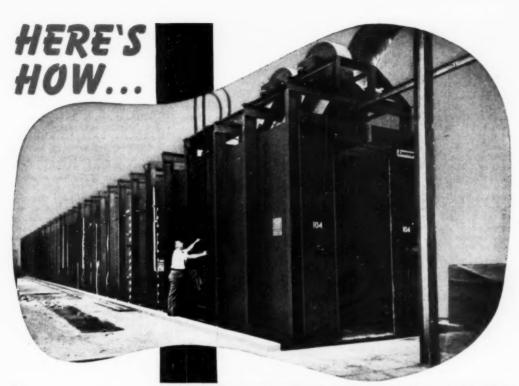
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Metal Progress; Page 248-B





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LINDBERG



FURNACES

Internal Stresses

(Starts on p. 242)

help, and the transgranular stresscorrosion cracking which distinctly depends on the existence of strong tension stresses and on peculiar conditions of service - mainly solutions of chlorides, particularly hot concentrated magnesium chloride.

Keating completes his article by examining the mechanism of stresscorrosion cracking. This is considered as a function of stress under corrosive influences and as a function of these influences in regard to the existing stress. Finally, he considers the question of the features which enhance or stop further propagation and branching of the initial cracks. He indicates that the idea of stress corrosion derives its validity from the acceleration of stress concentration due to corrosion and the acceleration of corrosion due to stress proceeding beyond the sum of the possible individual actions. But he frankly admits that the situation in this field is still too obscure

W. P. Rees contributed a very short, but extremely interesting, note

UNITED

on stress-corrosion cracking of steels in the presence of sulphur compounds (three pages). Such stresscorrosion failures were encountered in service when 18-8 stainless steel was subjected to oil that contained hydrogen sulphide. Laboratory tests have shown that hardened and tempered alloy steels are susceptible to stress-corrosion cracking in atmospheres of wet hydrogen sulphide or carbon disulphide.

Professor Hugh O'Neill's paper on internal stresses in railway materials (17 pages, 41 references) begins with a brief statement that stresses existing in iron castings, first investigated by Rodman in 1857, cannot be eliminated except by judicious heat treatment. From here he passes to an example of a cast bushing of high-lead, mediumcopper type (roughly 60% Pb, 37% Cu) containing nickel and sulphur as inhibitors of segregation. That bushing developed a plethora of cracks in storage after machining. but since it contained in spots the nonspecified oxygen to the amount of 4%, the role of stresses is rather doubtful. It might have been simply a poorly produced material.

Of real value to the reader is

Professor O'Neill's substantial treatment of the stresses developed in steel rails. But the table of internal stress values given by him indicates that the magnitudes of the stresses rarely reach 20,000 psi, and it is an open question how deleterious such stresses might be in a material with a yield point several times higher.

His next item of discussion is the shot blasting of springs. It is accompanied by hardness data for the shot-peened surfaces and the depth of the compressed layer. The compressive stresses were computed to reach as much as 90,000 to 130,000 psi.

Professor O'Neill then discusses stresses in boiler tubes that are fitted to fire-plates of arsenical copper by a process of internal mechanical expansion, where the residual tension stresses reach only 6000 psi., and the stresses in rivets. This latter subject is of considerable importance in itself for the tension stresses reach beyond 20,000 psi., even when the rivets are set at 1300° C., but the author does not consider it at any length.

The eighth and final division of O'Neill's paper deals with press fits.

(Continued on p. 252)

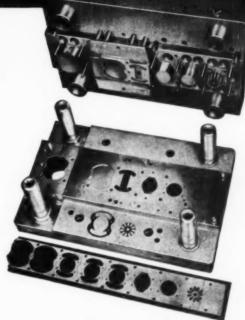


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EW ROCHELLE, N. Y.

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Internal Stresses

(Starts on p. 242)

shrink fits, wheels and tires; it is a very brief story.

E. H. Bucknall, W. Nicholls and L. H. Toft contributed a paper on delayed cracking in hardened alloy steel plates (19 pages, four references). It represents a report on a strictly experimental piece of research work in which hard steels obtained by quenching with and without low temperature (about 500° F.) tempering were given artificially induced stresses of 180,000 to 300,000 psi, and allowed to remain stressed until cracked or until the test was stopped (usually in 100 to 200 days). The test itself is very interesting. It consists in forming thin circular disks of steels with a central hole and a slight conicity. After heat treatment such disks are squeezed between a plate sup-

calculable stress is produced.

Of interest are the authors' diagram of internal stresses developed at different distances from the center and at opposite locations (top and bottom) under variable degrees

port and a nut, in which manner a

of flattening, and particularly a diagram of the influence of temperature. The life of a stressed conical disk decreases rapidly with increase in temperature from 20 to 100° F.

The final paper in the monograph, by J. A. Wheeler, discusses the stress system causing hard-zone cracking in welded alloy steels (eight pages, eleven references). The author starts with five statements that can be reduced to a single one: Transgranular cracking in welded structures occurs in a narrow zone adjacent to the weld (where a martensitic structure prevails under normal cooling conditions) provided the welded article is restrained from adjusting itself, the welding is done with an ordinary electrode, and the temperature in service is below 100° C.

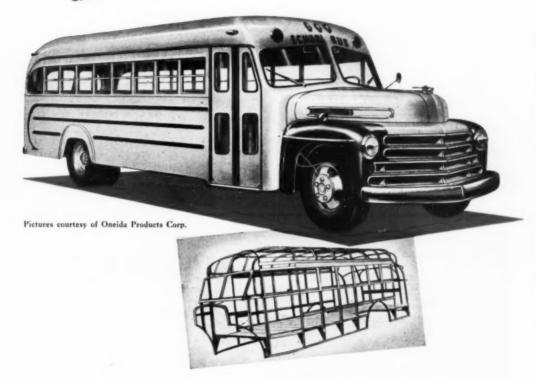
The author tested various steels that were heated to temperatures up to the solidus before air hardening. For one such steel (0.35% C, 0.60% Mn, 3.44% Ni, 1.70% Cr, 0.47% Mo) a diagram is presented showing that, after air cooling, such steels exhibit a hardness almost independent of the temperature to which they are heated, but the tensile strength drops sharply in the prox-

imity of the solidus, where the elongation too drops below 3%. But the elongation and reduction of area begin to drop even if the steel is heated to a temperature 300° C. below the solidus. Beyond these factual points the author very briefly restates ideas regarding the microstresses in martensite and the internal stresses produced by absorbed hydrogen, as propounded by other authors.

Conclusions of the Reviewer -The monograph on internal stresses is rather disappointing, but the subiect itself has some dubious characteristics. One might talk about microstresses the whole day through without saying anything of value, for microstresses are almost impossible as objects of experimental study and by no means easier as objects of mathematical analysis. All-over stresses-of the type whose study originated with Professor Heyn and was thoroughly improved by Sachs and others - are easier to know, easier to take care of and easier to make use of. But even here the situation is by no means clear. Some methods of such study produce only "average values" and (Continued on p. 254)

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August, 1949; Page 253

Internal Stresses

(Starts on p. 242)

nothing is less satisfactory than average stress values in engineering practice. Other methods (Heyn's and Sachs's) seem to be more basic and promising, but even the results of such studies give stress values that are averages for a given layer—not for a given point or a given direction. The curve of internal stresses so traced does not indicate the true surface stress nor the true axial stress. These must be obtained by extrapolation, and extrapolation is the worst method of getting facts.

In order not to be overly pessimistic, I would say that perhaps new methods can be developed, but one should not expect that any single experiment might produce more than an ultramicroscopic grain of truth. The solution of the internal stress problem lies in extensive and intensive testing, and the results of the tests must be properly coordinated and carefully studied in order to produce definite statements which can be related to engineering practice.—M. G. Corson

Surface Strengthening by Cold Rolling*

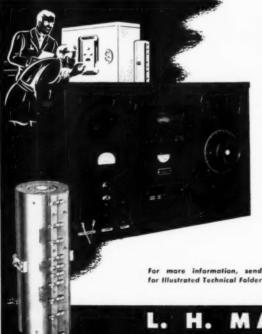
SURFACE HARDENING for the improvement of fatigue strength can be accomplished in several ways, but the hardening of cylindrical pieces by pressure rolling is easily controlled and forms the most satisfactory subject for experimental investigation. The paper by Föppl represents a most thorough study of the process. It covers ninety individual tests on two kinds of steel: a spring steel with 0.60% C. 1.9% Si and 0.83% Mn. and an alloy steel with 0.15% C, 1.5% Ni. 1.2% Mo and 0.8% Cr. The surfaces were hardened by pressure rolling bars 44 mm. in diameter and 200 mm. long between two rolls 40 mm. in diameter. One of these with a rounded edge forming a very small contact area with the test bar did the actual hardening, while the other

*Abstracted from "Measuring the Stresses and Plastic Deformations in Surface-Pressed Test Bars", by Hayo Föppl, Mitteilungen des Wöhler-Institute, No. 41, 1948, 67 p. one, with a flat edge, served merely as a support that would prevent bending of the test bar.

Among the factors investigated were the radius of curvature of the pressure roll, the pitch of the pressure spiral, the pressure applied and the number of rolling cycles. The measurements consisted in the determination of the length changes by comparison with standard specimens to a precision of 0.002 mm. and of the changes in diameters, which were reduced by etching the metal in dilute nitric acid. The thicknesses of the removed layers were computed from the losses in weight.

Pages 12 to 23 deal with the theory of the measuring process. In a very clear manner, without omitting any steps, the author develops his equations for the axial and tangential stresses at a given depth of hardened layer and simplifies them later to a graphical equation. His equation 25 permits computation of the amount of plastic deformation in that layer (which is frequently a hundred times greater than the elastic strain). In order to obtain uniform

(Continued on p. 256)



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CERAMICS DIVISION

Surface Strengthening by Cold Rolling

(Continued from p. 254)
data for comparison, all stresses
and plastic deformations are related to a standard depth of 0.1 mm.

The author's equations depend on four assumptions: The modulus is considered constant; Poisson's ratio is also assumed to be a constant and equal to 0.30; the elastic limit of stress is assumed to be constant; and the ratio of the tangential and axial plastic strains is assumed to equal 0.30. The author seems to consider his values of stress and strain accurate within 10%.

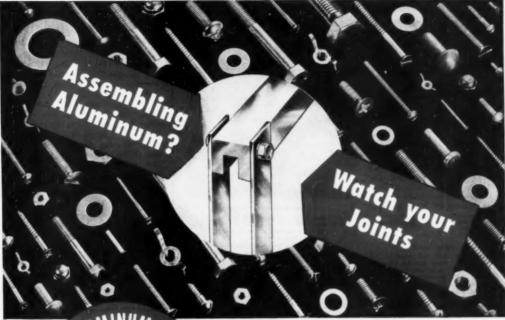
Seven basic and nine auxiliary diagrams cover the results obtained on the spring steel and three basic diagrams are drawn for the alloy steel. All are instructive. Of considerable interest is the fact that even a compression stress of 220,000 psi. in the hardened layer of the spring steel is below its elastic limit in compression. M. G. C.

Electroradiography*

T SEEMS that the author has created a new and simple tool for metallurgists. X-rays coming from a tube operated at 150,000 to 200,000 volts are made to pass through an optically opaque sheet of paper after the softer rays are screened off. They then strike the back side of a fine-grained film pressed with its sensitive layer toward the polished surface of the sample being studied. Photo-electrons develop in this surface and pass into the sensitive layer, producing a photochemical action enormously greater than the action of the hard rays can be. According to Trillat, the picture produced is so sharp and clear that it can be magnified as much as a thousand times, so that a single picture permits easy examination of the structure of a very large field, which is not possible with the ordinary microscope.

However, Trillat does not show any samples of photographs obtained by high magnification from his basic film; those which he does (Continued on p. 258)

*Abstracted from "Electroradiography and Its Applications in Metallurgy", by J.-J. Trillat, Revue de Métallurgie, Vol. 46, 1949, p. 79-83.





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Electroradiography

(Continued from p. 256)

show at 6 and 10× are quite good and suggest that it would be worth while to try his method on a large and systematic scale.

An important point about Trillat's method is that the sample does not have to be etched. The picture is formed as a result of the selective emission of electrons from the different constituents and from the grain boundaries. And the same film can be used as a macrograph and a micrograph. Trillat states that even ordinary Velox paper could be used instead of the film and that the whole process could take place in subdued light. The exposure lasts only a few M. G. C.

Jobs for Engineers*

THE ENGINEERING profession is outnumbered in size only by the teaching and nursing professions; engineering is the largest profession for men.

The employment outlook for engineers in the immediate future and for several decades ahead is good. according to this extensive survey. Annual demand for engineer graduates in the United States is estimated at 17,000 to 18,000. By 1960, when death and retirement losses to the engineering profession are expected to increase, the demand may rise to 21,000 to 22,000 a year. Employment trends, earnings, training and shifting among jobs and industries are analyzed for civil, mechanical, electrical, chemical and "mining and metallurgical engineers". (Unfortunately, the data available to the Bureau of Labor Statistics classified mining engineers with metallurgical engineers.)

Only seven pages of text are allotted specifically to "mining and metallurgical engineers". One statement that "the mining engineers are believed to have outnumbered metallurgical engineers" may be questioned. This section concludes: "The field of metallurgy should expand in the future. However, this field is not large and openings will probably continue to remain few compared to other fields of engineering." (Continued on p. 260)

*Comments by John W. W. Sullivan on "Employment Outlook for Engineers", bulletin of the U. S. Department of Labor, Bureau of Labor Statistics, Washington, D. C.

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August, 1949; Page 259

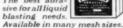


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Jobs for Engineers

(Starts on p. 258)

The latter part of that conclusion is rather remarkable; its source should be seriously challenged. Without metals modern civilization would revert to the Stone Age. Over 70 of the chemical elements are metals. Half of the metals remain to be developed commercially; therein lies tremendous opportunity for metallurgists and metallurgical engineers.

Two other conclusions concern the metallurgical profession: A comparison of earning power of engineers having a master's degree with that of engineers having a doctor's degree, reveals that the doctorate is worth more to mining and metallurgical engineers than to those in other divisions of engineering.

Concerning the occupational mobility of engineers, a greater proportion of those who were trained in mining or metallurgy changed to some other field of activity than those trained in any other major division of engineering. The changes appear to have been made easier alternative that mining and metallurgical training and experience are so varied that the engineers obtain an opportunity to qualify for positions in mechanical and civil engineering.

Undergraduate enrollment of mining and metallurgical engineers in the United States ranged from 2771 in 1931 to 5836 in 1948, with an interim high of 4570 in 1941 and a low of 696 in 1945.

The median base monthly salary for engineers in 1946 ranged from \$360 for chemical engineers to \$417 for mining and metallurgical engineers.

There were 7000 engineers in the United States in 1880 and about 350,000 in 1948. The rate of growth is diminishing; but there is every likelihood that the profession will continue to grow for some time. It is estimated that there will be 450,000 engineers in 1958. From 1880 to 1940, the engineering profession expanded 38-fold in the United States while the total number of workers in all occupations increased three-fold.

Five industries employ 75% of the engineers — manufacturing, mining, construction, transportation, and public utilities.

From 1939 to 1946, about 20% of the engineers replying to a questionnaire changed to a different industry. Engineers appear to have changed their industry more readily

(Continued on p. 262)



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steels to meet your individual requirements. Timken Graph-Mo is a general-purpose tool steel. Graph-Tung, Graph-Al, and Graph-M.N.S. are for special applications. For the latest information on all four graphitic steels, write for the new, enlarged 9th edition of the Timken Graphitic Tool Steel Data Book. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".





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Jobs for Engineers

(Starts on p. 258)
than their general field of employment or "class-of-worker" status. Most of the changes appeared to be in response to the shifting of industrial demands of the war and the postwar period. The report covers five types of movement of engineers — changes of employment location, industry, class of worker, field of employment, and from a specialized field of education to a different field of employment.

Other topics discussed in this bulletin are professional societies and organizations, registration and certification of engineers, census data on engineers, and a comparison of mailing list and respondent replies to questionnaires.

Strength of Alloys at High Temperature

THREE recent papers in Russian indicate the possible value of theory in the design of alloys for use at high temperature.

The first of these papers* concerns electron density and energy within the alloy crystal. Only a

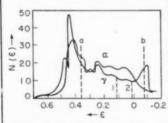


Fig. 1. Density of Electron States in α and γ Irons. ε is the energy of the electrons in Rydberg units and N(ε) is the density of states.

qualitative presentation of the principles is possible. The general aspect of the hot strength of homogeneous solid solutions having bodycentered cubic and face-centered cubic structures has been worked out on the basis of the $N(\varepsilon)$ curves for iron shown in Fig. 1. With the change in the total number of (Continued on p. 266)

*"Fundamental Principles of Alloying of Hot Strength Metallic Alloys", by K. A. Osipov, *Doklady Akad. Nauk S.S.S.R.*, Vol. 60, 1948, p. 1535-1538. FOR GREATER
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562. Alloy Steels

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563. Alloy Steels

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567. Blast Cleaning

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Bulletin 47, just off the press, contains more news on applications and developments of Easy-Flo and Sil-Fos alloys. Handy & Harman.

569. Brazing Alloy

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Completely descriptive booklet on Graphalloy a self-lubricating material for use particularly or bushings where oil lubrication is difficult or impractical. Graphite Metallissing Corp.

571. Castings

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"New Horizons for Microcasting". Austenal Laboratories, Inc.

572. Castings

New 40-page well-illustrated booklet, "Help Calumet Steel Make Your Castings Better", gives a practical summary of information needed to purchase electric furnace steel castings wisely and ecosonically. Calumet Steel Castings Corp.

573. Castings

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575. Castings

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New bulletin describes Pyrasteel grids, designed and built for endurance and permanence. Chicago Sieel Foundry Co.

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579. Castings, Steel

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Revolutionary injection pressure multiplier assures solid, dense castings. Built into the hydraulic injection cylinder – requires no additional space. This and other machines to meet every die-casting requirement are described in catalog. Kax Machine Co.

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Revealing book "How Magnesium Pays" gives case studies of its economical use in a wide range of products. Dow Chemical Co.

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592. Electrodes, Welding

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"Alcoa Aluminum Impact Extrusions" is the title of a new booklet giving up-to-date information on short-cuts to designing all types of parts by means of these new impact extrusion presses. Aluminum Co. of America.

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597. Forgings

Bulletin 65-C describes forgings being produced better, faster and at lower cost by high-production, heavy forging machines. Ajax Manufacturing Co.

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601. Furnaces

Bulletin 53 tells how new cyclone furnace can help reduce costs and improve quality of tempering, annealing, nitriding, and nonferrous heat treating Lindberg Engineering Co.

602. Furnaces, Laboratory

New "Lab-Type" furnace with gaa-tight retort offers self-contained unit of ample size for wide variety of lab operations. Fully described in bulletin F 327. Boder Scientific Co.

603. Furnaces, Laboratory

Bulletins 315 and 515 describe furnaces for low and high-temperature operation. Five different models for analysis, control and production in chemistry, metallurgy and manufacturing. Burrell Technical Supply Co.

604. Furnaces, Laboratory

New speed oven saves time and cost in labora-tory drying. Leaflet describes how samples are dried twice as fast by hot, filtered air driven at high speed. Harry W. Distert Co.

605. Furnaces, Laboratory

New type 056-PT incorporates all the best features of Hevi Duty laboratory furnace design. Complete specifications and details are listed in bulletin LAB-849. Heri Duly Electric Co.

606. Gas Burners

Latest methods of obtaining highest heating efficiency per unit of fuel are illustrated in bulletin IC-22 on Kemp Series "S" industrial carburetors. C. M. Kemp Mfg. Co.

607. Gears

Information on all types of gearing specifica-tions, including Neloy, spur, bevel, mitre, Sykes Herringbone. Available in bulletin No. 0. National Eric Co.

608. Gray Iron

Mechanical and engineering characteristics of gray iron, with details for designing cast com-ponents, all combined in new booklet furnished on request. Gray Iron Founders' Society.

609. Hardness Testers

Bulletin DH-114 contains full information on Tukon Hardness testers for use in research and industrial testing of metallic and momentallic materials. Also included in bulletin DH-7, giving experience in various fields. Witon Mechanical Instrument in various fields.

610. Heating and Drying

New high-pressure steam fan heater described in bulletin 109. Niagara Blower Co.

611. Heating Elements, Electric

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(Starts on p. 262)

valence electrons that occurs in going from titanium to nickel, the highest occupied levels for both crystal structures are found in the energy interval from a to b.

In the formation of solid solutions having structures analogous to α and γ iron, resonance or superposition of the $N(\varepsilon)$ curves characteristic of each of the components will occur. However, this generalized N(e) curve for the solid solution will be similar to that for a or y iron, since it is determined in a basically symmetrical crystal structure and since the greater contribution to the common $N(\varepsilon)$ curve will be made by the solvent component.

In plastic deformation the electrons must change their energy and distribution in the crystal structure. The probability of redistribution is lower (resistance to deformation is greater) the fewer are the permitted states of electrons in the upper occupied levels. On this basis the general principle can be stated: "A homogeneous solid solution with a minimum density of electron states in the region of the higher occupied levels of the N(E) curve must possess the maximum heat resistance." Probably the slope of the $N(\epsilon)$ curve in this vicinity is also significant. This density of states is less for y iron than for a iron.

Since the highest occupied state for y iron corresponds to position 1 of Fig. 1, and that for nickel (also face-centered cubic) corresponds to position b, it is predicted on the basis of this principle that the strength of iron at high temperature is affected only slightly by additions of nickel up to 50%, but is decreased by further addition of nickel.

On the other hand, the addition of a body-centered cubic element to a face-centered cubic solvent will result in greater hardness and strength at high temperature as a result of nonuniformity of the electron distribution. This applies also to the addition of an element having a crystal structure with an N(E) curve significantly different from that of the face-centered cubic structure.

Metals with different crystal structures and widely separated in the periodic table tend to form (Continued on p. 268)

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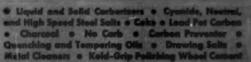
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Strength of Alloys at High Temperature

(Starts on p. 262)

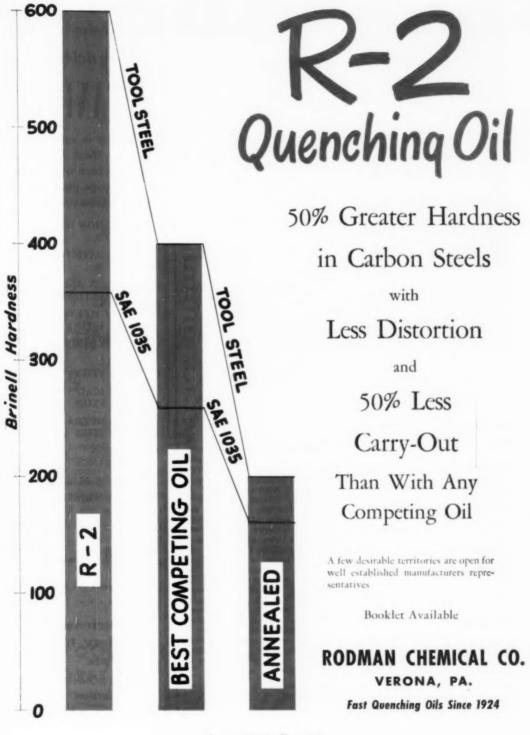
intermetallic compounds. Since there is no doubt that the electron distribution in such metals also differs sharply, it is reasonable to expect an increase in the strength of the face-centered cubic solid solution on the simultaneous alloying of it with several components that form intermetallic compounds among themselves.

The second paper by Osipov* concerns the correlation between melting and strength. The high-temperature strength of single-phase alloys can be estimated from their ease of melting. Thus, the influence of components of an alloy on its strength can be judged from the trend of the liquidus and solidus curves or surfaces. Refractory intermetallic compounds would be expected to have the best high-temperature strengths, although they might be brittle.

The close relation between the melting temperature and the hightemperature strength of alloys is explained by the fact that near the temperature of crystallization both the liquid and the solid have much in common in the distribution of atoms, in the character of thermal motion, and in the force of interatomic interaction, and that the same binding forces apply to mechanical strength and to the resistance to melting. This relation is more easily revealed for pure metals than for alloys, especially those alloys capable of dispersion hardening. However, experimental data on iron-chromium, iron-nickel, cobalt-nickel, and manganese-nickel alloys apparently confirm these views.

A series of cast alloys were prepared using high-purity metals and were annealed for 48 hr. in vacuum at 1150 or (for manganese-nickel) 1000° C. At the end of annealing the specimens were water quenched. The quenched specimens, 2.6 mm. in diameter and 60 or 85 mm. long, were tested for comparative high temperature strength at 1100° C. by the method of L. L. Kornilov. In this method the mechanical strength is evaluated according to the deflection of the specimen under the action of centrifugal force. The (Continued on p. 270)

*"The Relation Between the Melting Temperature and the High-Temperature Strength of Alloys", by K. A. Osipov, Doklady Akad. Nauk S.S.S.R., Vol. 61, 1948, p. 71-74.





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Strength of Alloys at High Temperature

(Starts on p. 262)

alloy showing the smaller deflection has the better high-temperature strength.

For 60-mm. bars of manganesenickel alloys, deflections of 11, 5, and 3 mm. were produced in the 70, 80, and 90% Ni alloys when subjected to 1500 r.p.m. for 5 min. Since the melting temperature increases about 200° C. from 70 to 90% Ni, the predicted change of high-temperature strength is observed. Similar results were obtained for the other three alloy systems.

From data on the iron-chromium system it was concluded that alteration of the crystal structure has little influence on the strength at high temperatures, in contrast with the great influence at low and moderate temperatures. Also, the data on iron-nickel alloys showing a linear change of strength with composition, support Bochvar's theory that reversal of the relation between composition and properties can occur as the temperature of testing is raised.

Bochvar has proposed that the interaction by the co-existing phases is basic to the behavior of heterogeneous alloys at high temperatures, and that plasticity is a result of rapid rates of change of solubility with temperature. However, it has been shown that in some alloy systems the hightemperature strength of the heterogeneous alloys is less than the strength of the single-phase alloy, while in other systems the reverse is true. An attempt is made* to explain this difference in terms of the transition zone that exists between the grains of a single-phase alloy, as compared with the zone between the two different phases in a heterogeneous alloy.

The structure of the transition zone in heterogeneous alloys can vary greatly depending on the character of the interacting phases. Between two different solid solutions there is a less orderly distribution of atoms and less directed chemical bonds than between a solid solution and a chemical compound. This zone can be considered as an unstable state, since in (Continued on p. 272)

*"Factors in the High-Temperature Strength of Heterogeneous Alloys", by K. A. Osipov, Doklady Akad. Nauk S.S.S.R., Vol. 62, 1948, p. 493-495. The series of 20 articles on

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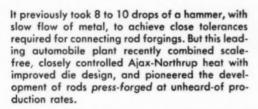
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Strength of Allovs at High Temperature

(Starts on p. 262)

a given system co-existing phases accompany stable formations. Small changes in thermodynamic conditions produce rapid changes in the grain-boundary transition zone. and contribute to the transfer of its substance into one or the other of the adjoining grains.

The surface tension of the transition zone also can contribute to its change, since this tension can cause flow similar to the viscous flow of amorphous bodies. For pure metals, where there cannot be mutual solubility of phases, it has been shown that plastic deformation at small loads and high temperatures is dependent on viscous flow at the grain boundaries. The mechanism of flow can be assumed to be the same as that of diffusion.

The factors that contribute to viscous flow of the transition zone and thus increase the plasticity of the alloys are undoubtedly those that increase diffusion at the crystal boundaries. The most important of these factors is the melting temperature of the transition zone. since at a given temperature diffusion is more rapid in a substance having a lower melting point. In eutectic systems the transition zone has a lower melting temperature than either of the pure phases; therefore, the high-temperature strength is lower for heterogeneous alloys in eutectic systems. This conclusion is valid only for testing temperatures at which diffusion is rapid. Similarly, in peritectic systems, the high-temperature strength of heterogeneous alloys is intermediate between the strengths of the two pure phases.

Other factors that depend on the nature of the interaction between co-existing phases are: (a) the structure and composition of the transition zone, (b) the mutual solubility of the phases and its variability with temperature, and (c) the stress in the transition zone.

Diffusion occurs more slowly in the transition zone between a solid solution and a chemical compound than in the zone between two different solid solutions. Diffusion occurs more rapidly the smaller the mutual solubility of the phases. Stresses in the transition zone can increase the rate of diffusion.

Thus, the effect of heterogeneity in alloys on the high-temperature strength can be diverse. 63



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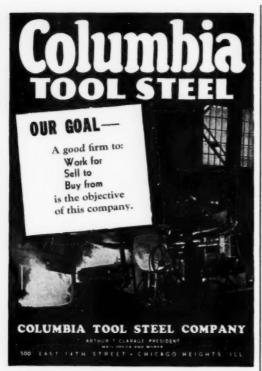
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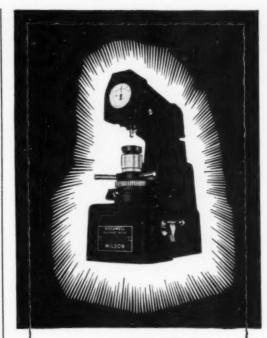
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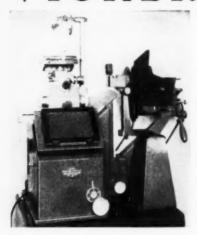
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RULES FOR ENTRANTS

Work which has appeared in previous Metallographic Exhibits is unacceptable

Photographic prints shall be mounted on stiff cardboard. each on a separate mount. Each shall carry a label giving:

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Classification of entry Material, etchant, magnification

Any special information as desired

Transparencies or other items to be viewed by transmitted light must be mounted on light-tight boxes wired for plugging into an ordinary lighting circuit, and built so they can be fixed to the wall

Exhibits must be delivered between Oct. 1 and Oct. 12. 1949, preferably by prepaid express or registered parcel post.

Address: Metallographic Exhibit, c/o W. H. Eisenman National Metal Congress and Exposition Cleveland Public Auditorium. Cleveland, Ohio

CLASSIFICATION OF MICROGRAPHS

- 1. Cast Irons and Cast Steels
- 2. Toolsteels (except carbides)
- 3. Irons and Allov Steels (excluding stainless) in Wrought
- 4. Stainless and Heat Resisting Steels and Alloys
- 5. Light Metals and Alloys
- 6. Heavy Nonferrous Metals and Alloys
- 7. Powder Metals (and carbides) and Compacts
- 8. Weld Structures (including brazed and similar joints)
- 9. Series of Micros showing Transitions or Changes During
- 10. Surface Phenomena and Macrographs of Metallurgical Objects or Operations (2 to 10 diam.)
- 11. Results by Non-Optical or other Unconventional Tech-

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a first prize (a blue ribbon) to the best in each classification. Honorable Mentions will also be awarded other photographs which in the opinion of the judges closely approach the winner in excellence.

A Grand Prize, in the form of an engrossed certificate, and a money award of \$100 will be awarded the exhibitor whose work is adjudged "best in the show", and his exhibit shall become the property of the American Society for Metals for preservation and display in the Sauveur Room at the Society's Headquarters. All other exhibits will be returned to owners by prepaid express or registered parcel post during the week of Oct. 23, 1949.

Entrants living outside the U. S. A. will do well to send micros by first-class letter mail endorsed "May be opened for Customs inspection before delivery to addressee".

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- Contestants must be members of the American Society for Metals.
- Contestants shall submit typewritten manuscripts, supported by photographs or drawings and cost sheets.
- Text should not exceed 1000 words (approximately three typewritten, double-spaced pages).
- Subject matter shall conform to the ECONOMY-IN-PRODUCTION theme, and fall within one or a combination of the following areas of interest to the American Society for Metals:
 - · Steel refining.
 - Mill operations, ferrous and nonferrous.
 - · Production of castings.
 - Improved applications of specific metals and of such metal-forms as castings, forgings, stampings, weldments, powder metal parts, tubing.
 - Forging, stamping and press-shop operations.
 - Machining operations that involve improved application of toolsteels, tool materials, cutting compounds or the metallurgical condition of the work being machined.

- Heat treatment-equipment, processes and supplies.
- · Welding, brazing, and mechanical joining.
- · Surface cleaning and finishes.
- Inspection of mass production.
- All entries must describe actual achievements; names of individuals, plants and products involved must be cited.
- Cash awards will be made by a committee of judges appointed by the President of the American Society for Metals. Their decision will be final.
- If the judges find other entries to have special merit, an appropriate citation and certificate will be issued.
- Submission of entries shall be regarded as evidence of release for publication by the American Society for Metals.

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